2.0 ENVIRONMENTAL SETTING

Coastal Alabama, defined as the southern portions of Mobile and Baldwin Counties (Figure 2-1), is economically diverse and contains multiple coastal environments (Hummell, 1996). The outer coast extends approximately 90 km from about 87°30' longitude at Perdido Pass to about 88°25' longitude at Petit Bois Pass. There are about 75 km of shoreline along the open Gulf at about 30°15' latitude (Chermock et al., 1974). The offshore State-Federal jurisdictional boundary marks the direct landward limit of the study area; however, the ultimate use of sand extracted from the OCS is for beach replenishment along the Alabama outer coast. Consequently, a description of the environmental setting from the outer coast to the OCS is pertinent for addressing the overall study purpose.

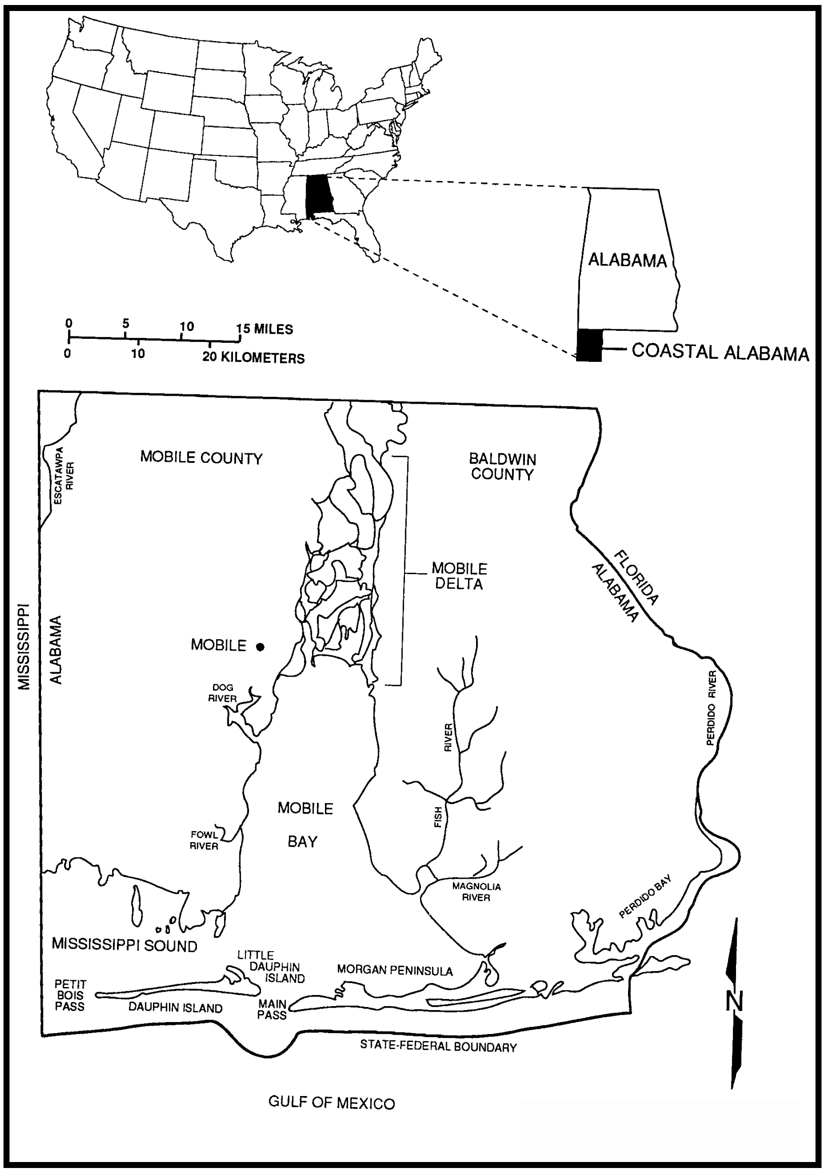

Figure 2-1. Coastal Alabama and vicinity (from Hummell, 1996).

Dauphin Island is the westernmost beach environment in coastal Alabama. The island is approximately 25 km long and extends from Main Pass at the Mobile Bay entrance to Petit Bois Pass, a 7-km-wide tidal inlet separating western Dauphin Island, Alabama and eastern Petit Bois Island, Mississippi (see Figure 2-1). The western two-thirds of Dauphin Island is a low-relief, washover barrier that is subject to overwash by Gulf of Mexico waters during tropical storms and hurricanes (Nummedal et al., 1980; Byrnes et al., 1991; Hummell, 1996). Maximum relief along this portion of the island is about 2 m relative to mean water level (MWL), except for dune features that may reach 3 m MWL in elevation. Island width varies between about 300 and 800 m. Currently, the main channel at Petit Bois Pass is located adjacent to Dauphin Island and extends to about 7 m below the MWL (McBride et al., 1991). The eastern end of Dauphin Island has an average elevation near the beach of about 3 m MWL; however, an extensive interior dune system that reaches an elevation of approximately 14 m MWL exists north of beach deposits on top of existing Pleistocene coastal deposits (Otvos, 1979).

Seaward of the beach along eastern Dauphin Island, an ephemeral, subaerial sand deposit called Pelican Island is associated with the ebb-tidal delta for Main Pass. This feature is prominent in its impact on shoreline response along eastern Dauphin Island (Parker et al., 1997). The island has continuously changed its shape, size, and location throughout the historical record in response to storm events and normal wave and current processes (Hummell, 1996).

Along the eastern Alabama coast in Baldwin County, the shoreline extends approximately 50 km from Morgan Point, at the eastern margin of Main Pass, along the Morgan Peninsula east to Perdido Pass (Figure 2-1). The Morgan Peninsula forms the southeastern terminus of Mobile Bay and consists of an extensive beach backed by parallel dunes and numerous sub-parallel beach ridges, formed as a result of net longshore sediment transport processes (Bearden and Hummell, 1990; Stone et al., 1992).

2.1 OFFSHORE SEDIMENTARY ENVIRONMENT

Seafloor topography and Holocene sediment distribution on the Alabama EEZ reflect a combination of processes, including regression during the late-Pleistocene and reworking of the exposed shelf surface by ancient fluvial systems, and reworking of the exposed shelf surface by coastal processes during the subsequent Holocene rise in sea level (Ludwick, 1964; Parker et al., 1997). Redistribution of sediment by waves and currents during transgression partially or totally destroyed geomorphic features associated with Pleistocene fluvial environments. Concurrently, these same processes formed modern shelf deposits as subaerial coastal features became submerged and reworked during relative rising sea level. As such, much of the shelf offshore Alabama is sand (Figure 2-2) (Ludwick, 1964; Doyle and Sparks, 1980; Parker et al., 1997). On the inner shelf offshore Dauphin Island, an extensive deposit of sandy mud occurs as a result of sediment discharge from Mobile Bay through Main Pass (Figure 2-3; U.S. Army Corps of Engineers, 1984; Parker et al., 1997). Parker et al. (1992) indicate that sediment type can change from sand to mud over a distance of several meters within the large Mississippi-Alabama sand facies.

Parker et al. (1992) suggest that much of the variation is due to changes in bathymetry. Large ridges on the eastern part of the Alabama shelf extend for several hundred meters in length, a couple of hundred meters in width, and are composed of sand. Shell gravel is common on the landward flanks of the ridges with mud occasionally depositing in the troughs between ridges (Parker et al., 1992; McBride and Byrnes, 1995; Parker et al., 1997).

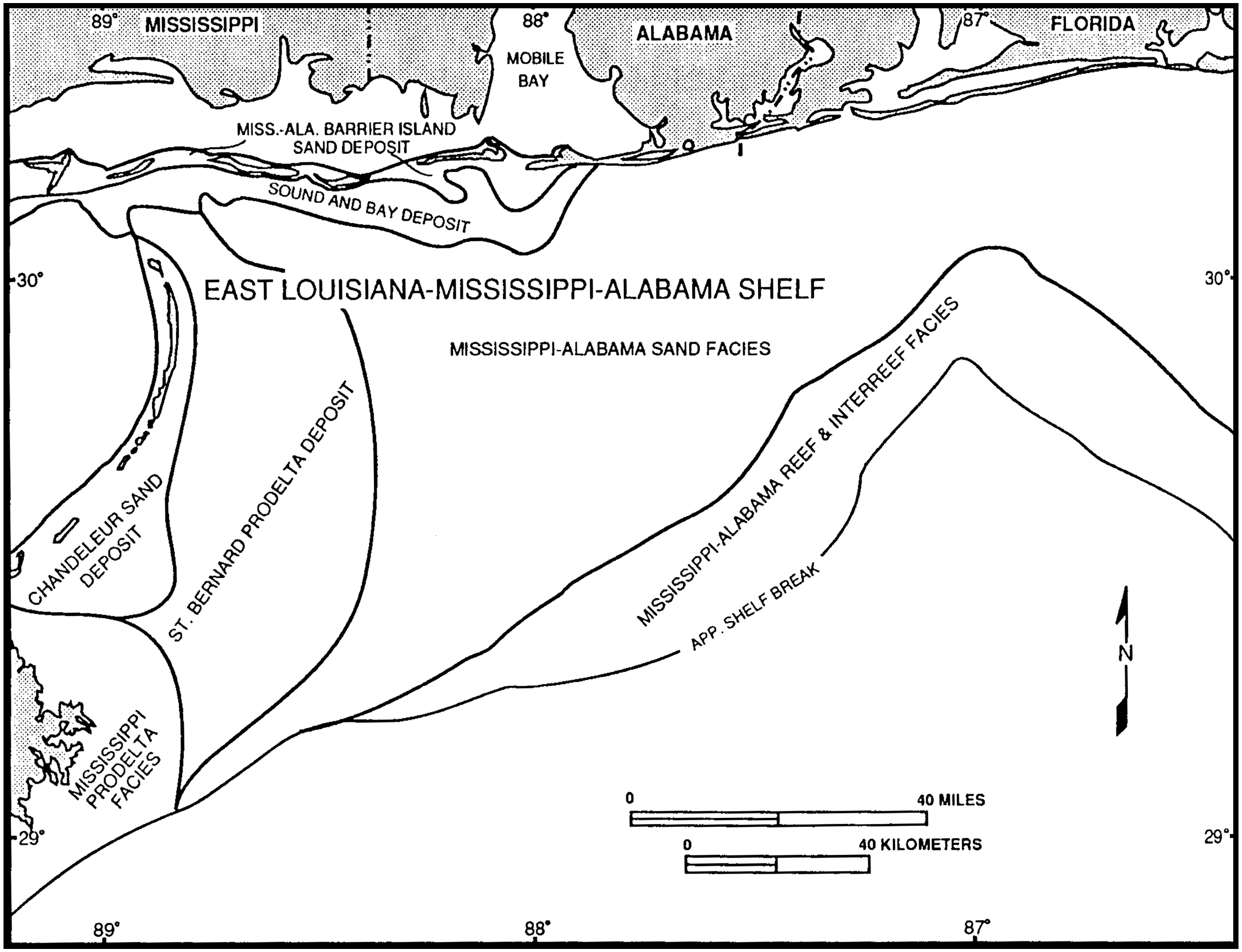

Figure 2-2. Sedimentary facies on the east Louisiana-Mississippi-Alabama shelf (after Ludwick, 1964; from Parker et al., 1997).

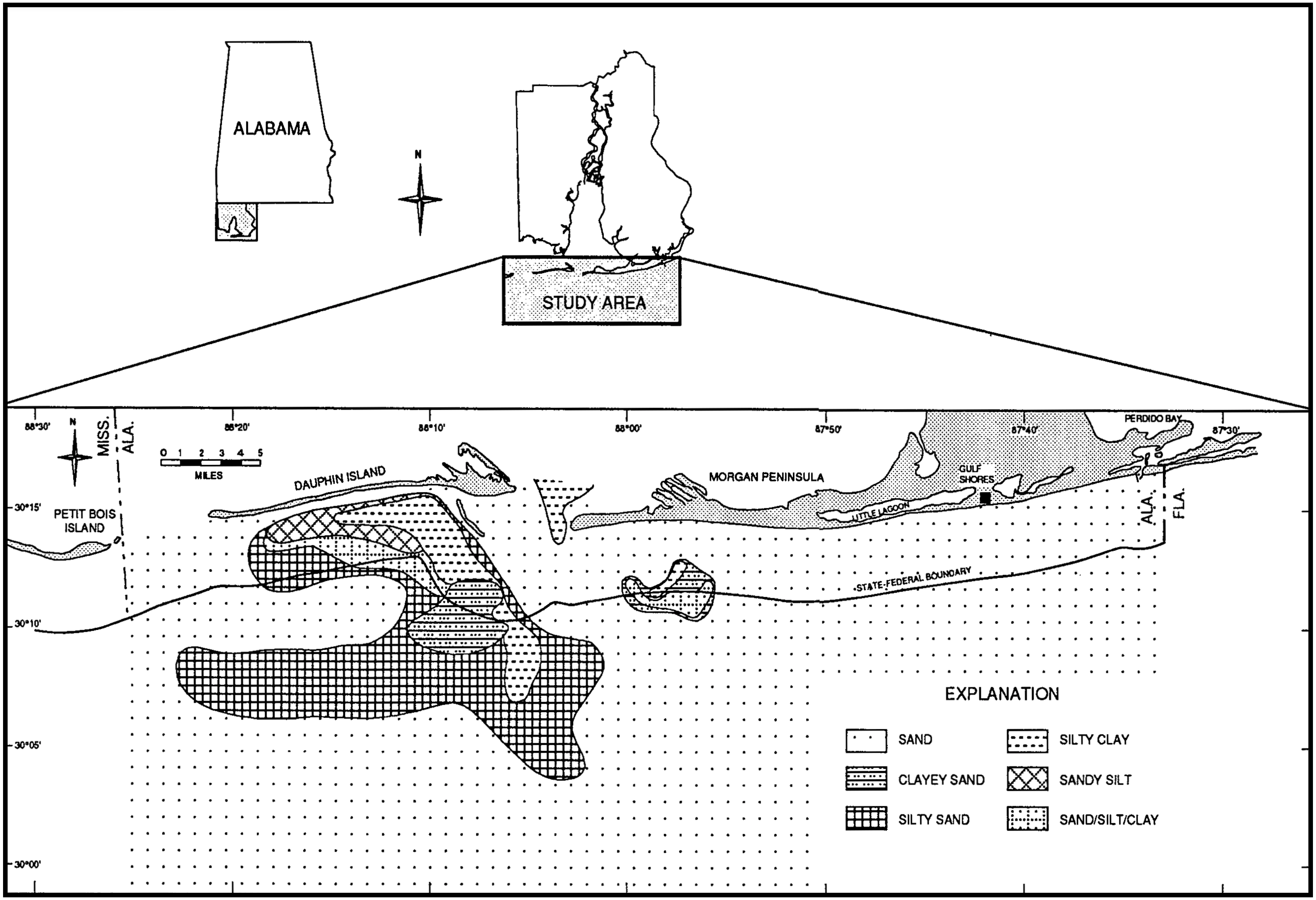

Figure 2-3. Surface sediment texture map compiled from previous sediment texture data in the study area (from U.S. Army Corps of Engineers, 1984).

2.1.1 Seabed Morphology

The Alabama continental shelf can be divided into two regions based on regional geomorphology and hydrology (Parker et al., 1997). The eastern shelf extends from the Alabama-Florida state boundary near Perdido Pass to Main Pass (see Figure 2-1). The western shelf extends from Main Pass to the Alabama-Mississippi state boundary at Petit Bois Pass. The large ebb-tidal delta at Main Pass is approximately 16 km wide, extends about 10 km offshore (Hummell, 1990), and separates the two regions (Figure 2-4). The subaerial portion of the ebb-tidal delta consists of Pelican Island, and occasionally Sand Island (an ephemeral shoal southeast of Pelican Island), both of which lie in the western shelf region.

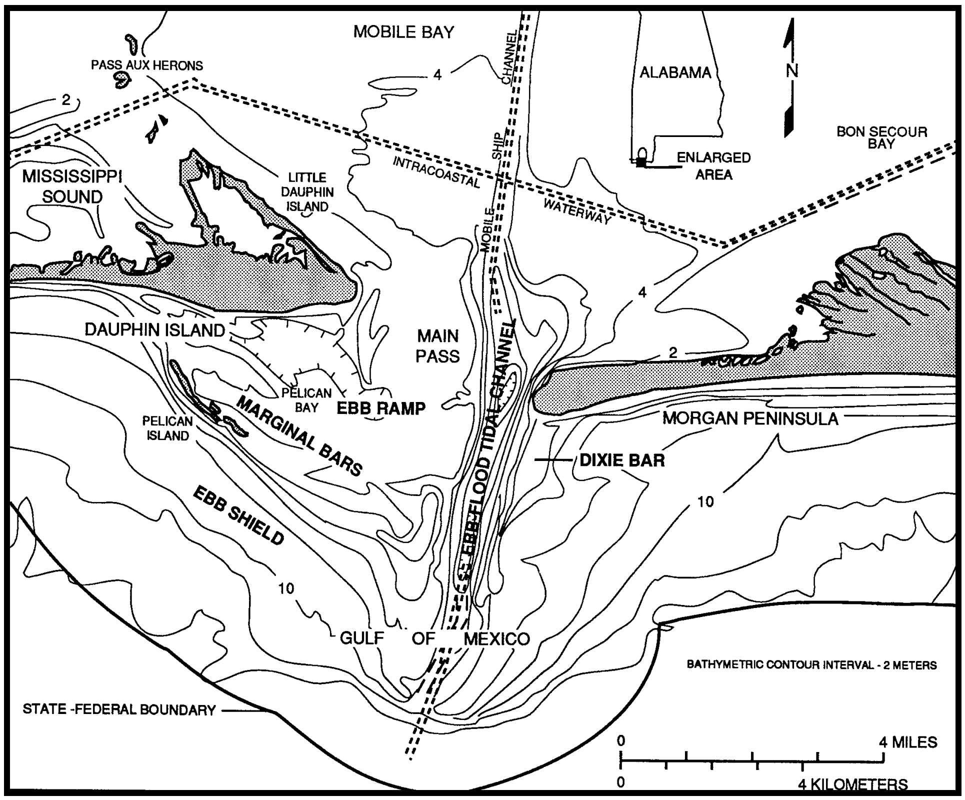

Figure 2-4. Geomorphology of the ebb-tidal delta seaward of Mobile Bay entrance (from Hummell, 1996).

The eastern portion of the study area is dominated by numerous shelf and shoreface sand ridges and swales that trend northwest to southeast (see Figure 1-1; McBride and Byrnes, 1995; Parker et al., 1997). The ridges are considered shoreface-attached and detached (Parker et al., 1992), and they form an oblique angle to the shoreline that opens to the east. Some of the ridges were identified by Parker et al. (1997) as pre-Holocene paleotopography draped with Holocene sand, rather than modern deposits resulting from marine hydrodynamic processes. The ridges average 6 km in length and range from 1 to 11 km long. Ridge widths range from 1 to 4 km with spacing between ridges varying between 1 and 7 km. Ridge side slopes average about 1°, and relief above the surrounding seafloor ranges from 1 to 5 m (McBride and Byrnes, 1995). The ridges recognized as shoreface-attached or shoreface-detached generally form opening angles with the east-west trending shoreline of 30 to 60°. Ridges formed as pre-Holocene paleohighs generally are oriented nearly perpendicular to the shoreline, reflecting their fluvial origin.

A large southwest-trending shoal, located approximately 16 km east of Mobile Point, is prominent in the eastern part of the study area (Figure 1-1). Although its origin is not known, evidence from Parker et al. (1997) suggests that it may be a drowned sand spit during the early Holocene as the western end of the Morgan Peninsula. Alternatively, it could be the remnants of a large ebb-tidal delta formed when an inlet was present through Morgan Peninsula. The sand shoal extends about 14 km offshore and has almost 6 m topographic relief, a potentially substantial sand resource target. The occurrence and character of ridges on the eastern shelf of the Alabama EEZ are described in detail by McBride and Byrnes (1995).

The upper shoreface of the eastern shelf region is much steeper than the western shelf region, and gradients range from 8 to 12 m/km (McBride and Byrnes, 1995; Parker et al., 1997). However, the eastern shelf surface from the shoreline to the shelf break averages approximately 1 m/km.

The western half of the study area, from Main Pass west to Petit Bois Pass, has relatively few geomorphic features compared with the eastern part of the study area. Shoals associated with deposition near the entrances to Main Pass and Petit Bois Pass are prominent; however, the shelf seaward of Dauphin Island is smooth and concave. The marginal shoals of the ebb-tidal delta are quite shallow to the west of Main Pass (see Figure 2-4; Pelican Island is subaerial and Sand Island is intermittently subaerial). Hummell (1990) discusses the importance of these features to sediment transport patterns along the shoreline of eastern Dauphin Island. Overall, the shelf surface in the western half of the study area slopes at about 1.5 m/km.

2.1.2 Surface Sediments

Surface sediments throughout the study area are composed of two primary facies. The Mississippi-Alabama Sand Facies dominates the eastern portion of the study area (Figure 2-2; Ludwick, 1964). It consists predominantly of well-sorted clean quartz sand, with shelly sands occurring locally. McBride and Byrnes (1995) characterize samples taken from this area as >90% sand and <3% mud. Median grain size ranges from 0.14 to 0.46 mm or fine-to-medium sand. Ludwick (1964) characterized the sand in this area as 93% terrigenous and 7% carbonate, with a median grain diameter of 0.18 mm. Doyle and Sparks (1980) found the same general trend and named the facies the Mississippi-Alabama-Florida (MAFLA) sand sheet.

Along the coast between Little Lagoon and Dauphin Island is the Nearshore Fine-Grained Facies defined by Ludwick (1964) (Figure 2-2). This facies is similar to that found in Mobile Bay and Mississippi Sound (Chermock et al., 1974). Sand, muddy sand, sandy mud, and mud occur in water depths less than 20 m in a zone about 11 km wide. Near the Mobile Bay entrance, the zone extends seaward to encompass the ebb-tidal delta of Main Pass, before pinching out to the east near Little Lagoon.

Parker et al. (1997) collected 59 bottom sediment samples throughout the study area to characterize surface sediment distribution (Figure 2-5). Eight sediment facies were identified in the Alabama EEZ, two of which (graded shelly sand and echinoid sand facies) were found in 37 of 59 locations. The third most common surface sediment facies was orthoquartzite. Together, the three most common sand facies are represented in 81% of the samples (Figure 2-6), most of which are found in the eastern part of the study area, seaward of the Morgan Peninsula and Gulf Shores. Another large-scale pattern that is apparent is the presence of a muddier facies near the Main Pass of Mobile Bay. Sediment from Mobile Bay contributes fine-grained material to the shelf, particularly during times of heavy flow. Much of the fine-grained sediment is carried as a sediment plume offshore and to the west of Main Pass, due primarily to dominant wind, wave, and tidal current dynamics between the Bay and the Gulf (Wiseman et al., 1988; Stumpf and Gelfenbaum, 1990).

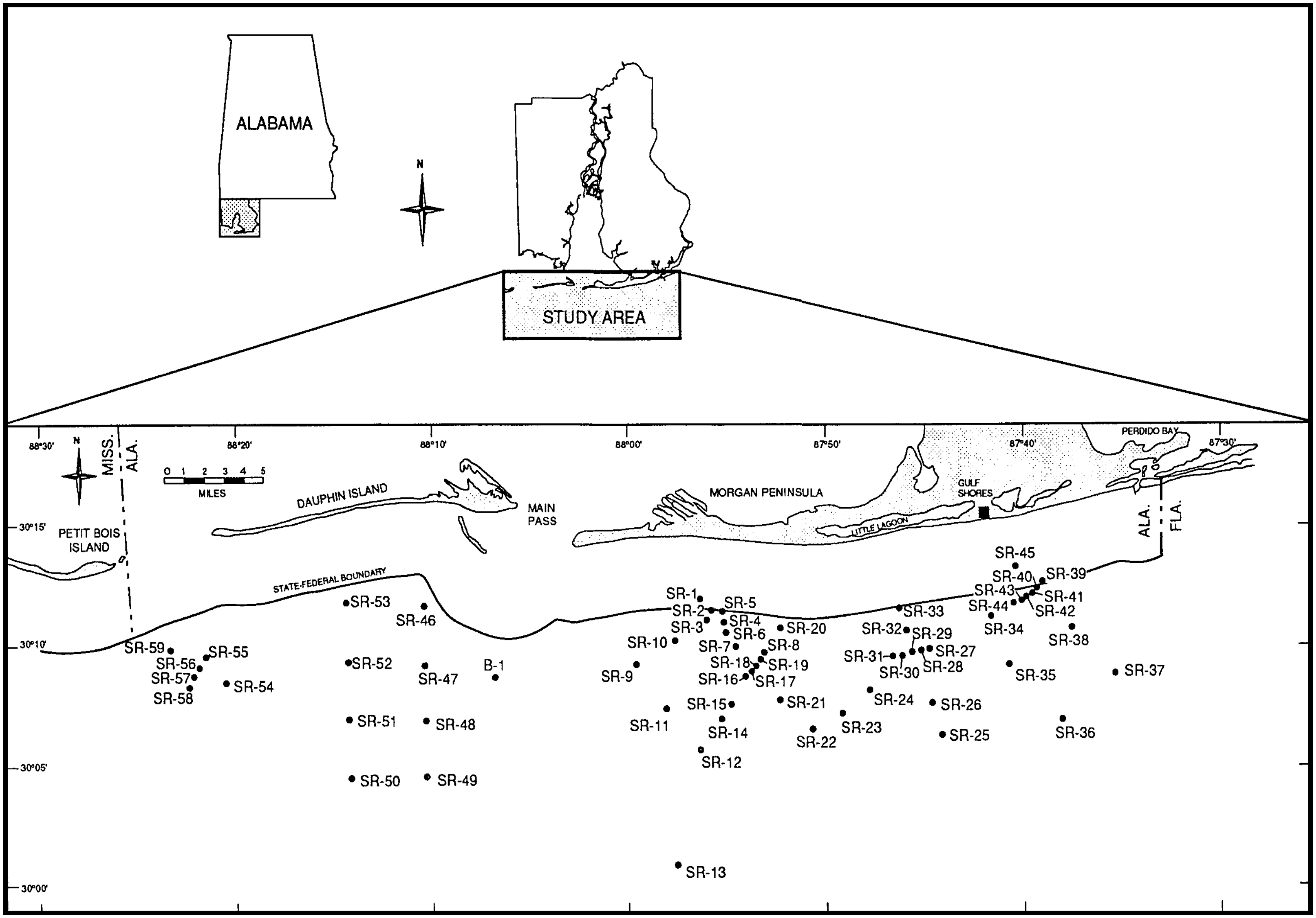

Figure 2-5. Vibracore, boring, and bottom grab locations in the Alabama EEZ study area (from Parker et al., 1997).

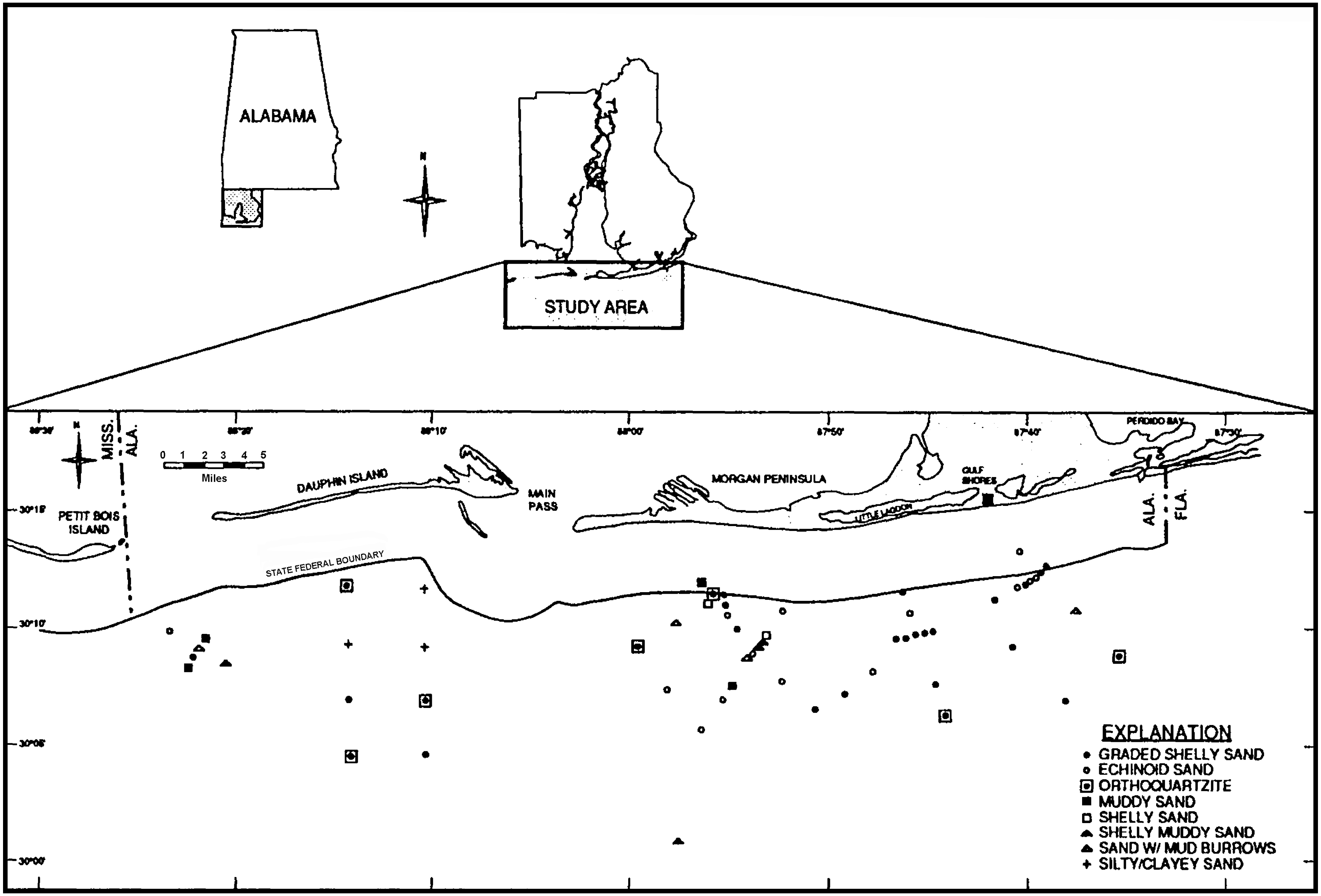

Figure 2-6. Surface facies distribution in the Alabama EEZ study area (from Parker et al., 1997).

Parker et al. (1993, 1997) illustrate the distribution of fine-grained sediment in the western portion of the study area based on limited samples (Figure 2-7), whereas Hummell and Smith (1995, 1996) use U.S. Army Corps of Engineers data to summarize the distribution of bottom sediment seaward of and adjacent to Main Pass and Dauphin Island (U.S. Army Corps of Engineers, 1984). Figure 2-8 illustrates the distribution of bottom sediment in the western portion of the study area where the influence of fine-grained sediment from Mobile Bay is recognized as areas of silty clay, silty sand, and sandy silt on an otherwise sandy shelf surface. Although the dominant surface sediment distribution in the vicinity of Area 4 is shown as sand/silt/clay to silty sand, Hummell and Smith (1996) collected additional surface sediment and vibracore samples to augment Parker et al. (1997) and U.S. Army Corps of Engineers (1984), and they identified a fine-to-medium sand deposit in the southeast quadrant of the area (Figure 2-9).

2.1.3 Subsurface Deposits

The Holocene geologic framework of the Alabama EEZ has been document by Parker et al. (1993, 1997), Hummell (1996), and Hummell and Smith (1996). Parker et al. (1997) obtained 59 vibracores from throughout the study area to document the history of sediment deposition on the continental shelf within the study area, with particular emphasis on identified potential sand resource areas. Based on core data analysis, five primary Holocene lithofacies were identified for the study area. They include a clean sand lithofacies, a graded shelly sand lithofacies, a dirty sand lithofacies, a biogenic sediment lithofacies, and a muddy sediment lithofacies. The sedimentologic characteristics of these facies are detailed in Parker et al. (1997; p. 33-71). As a summary, Figure 2-10 provides a generalized composite stratigraphic sequence of facies in the study area. Overall, much of the inner shelf of the Alabama EEZ is composed of a shelf sand sheet depositional environment formed during Holocene transgression. It is a deposit that grades into other sand depositional environments that have been reworked by high-energy storm events, as well as non-storm currents and bioturbation (Parker et al., 1997). On the eastern shelf region, numerous sand ridges have formed on top of the sand sheet in response to local and regional hydrodynamics (Swift and Niedoroda, 1985; McBride, 1997).

The western portion of the study area contains greater variability in depositional characteristics due to the influence of fine-grained sediment from Mobile Bay. The muddy sand lithofacies is common on the shelf west of Main Pass and seaward of Dauphin Island. Hummell and Smith (1996) used the classification criteria of Parker et al. (1993, 1997) to describe the lithology of deposits in Sand Resource Area 4. Hummell and Smith (1995, 1996) used 28 additional vibracores and seven Exxon foundation borings to determine the best location for a sand resource target in Area 4. Overall, sand deposits on the western shelf were finer-grained relative to shelf deposits to the east.

2.1.4 Sand Resource Areas

The resource potential of offshore sand deposits within the study area was documented using geologic data from Parker et al. (1993, 1997) and Hummell and Smith (1995, 1996). In addition, sand volume estimates for Resource Areas 1, 2, and 3 have been updated by the GSA (Hummell, 1999) using newly acquired vibracores. A comparison of sediment characteristics (size and color) from each sand resource area with beach sediment size from eroding Gulf shorelines was completed by Parker et al. (1997) to document resource compatibility. Based on shoreline change trends, Parker et al. (1997) and Hummell and Smith (1996) documented three shoreline zones within the study area as eroding shoreline segments. They included eastern Dauphin Island, the Gulf shoreline south of Little Lagoon, and the beach downdrift of Perdido Pass.

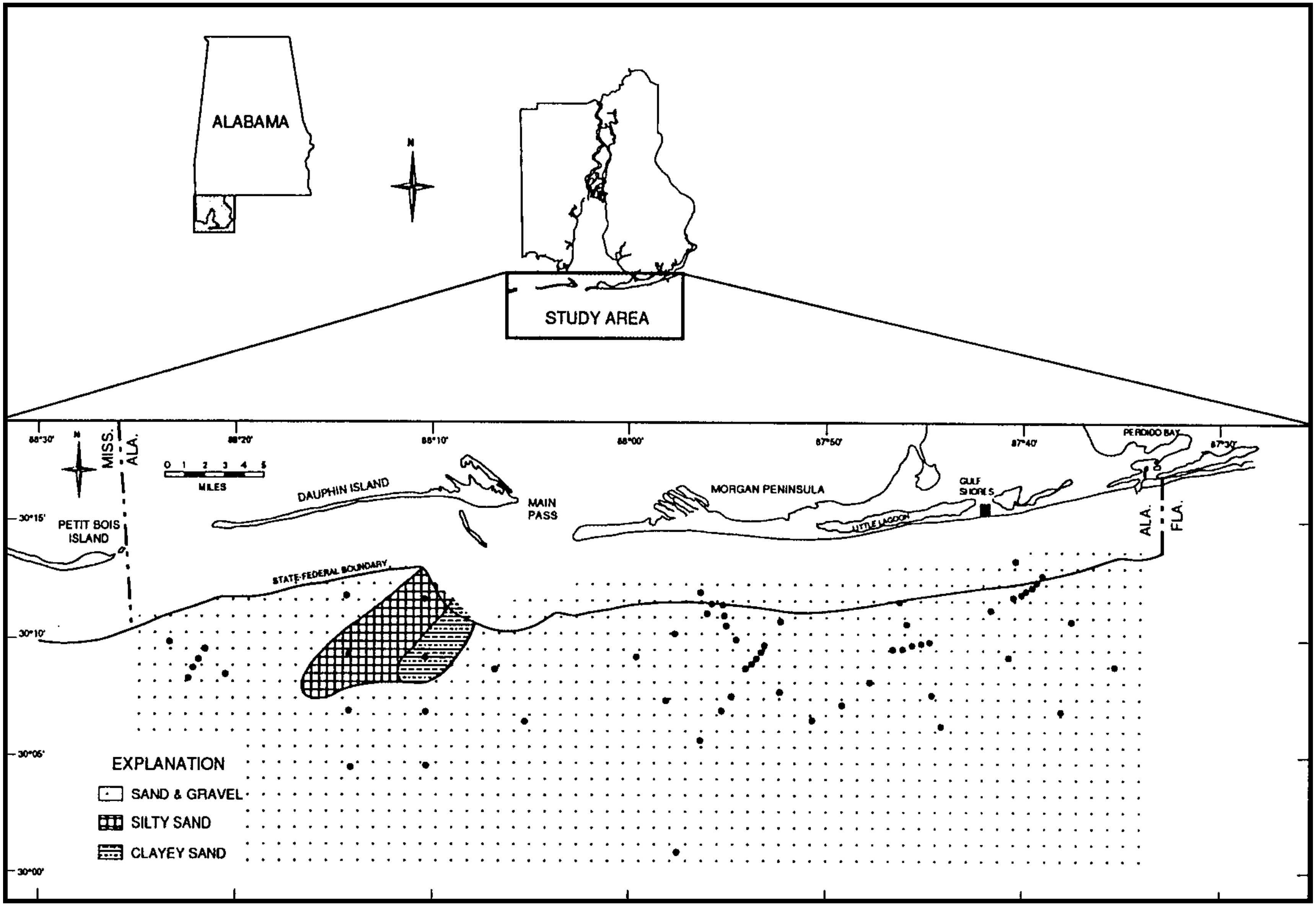

Figure 2-7. Surficial sediment textures in the Alabama EEZ study area (from Parker et al., 1997).

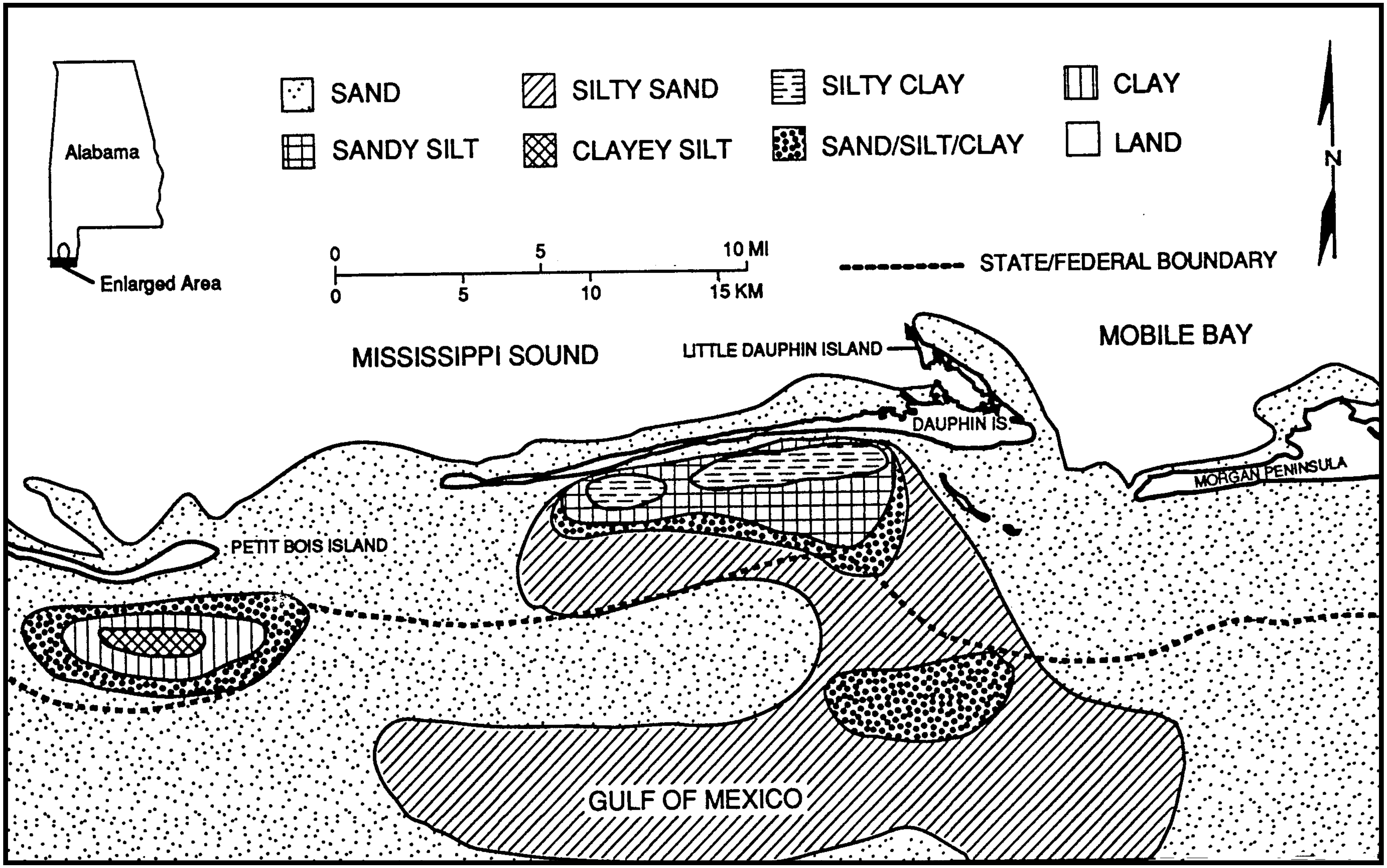

Figure 2-8. Surface sediment distribution in the west Alabama inner continental shelf (from Hummell, 1996).

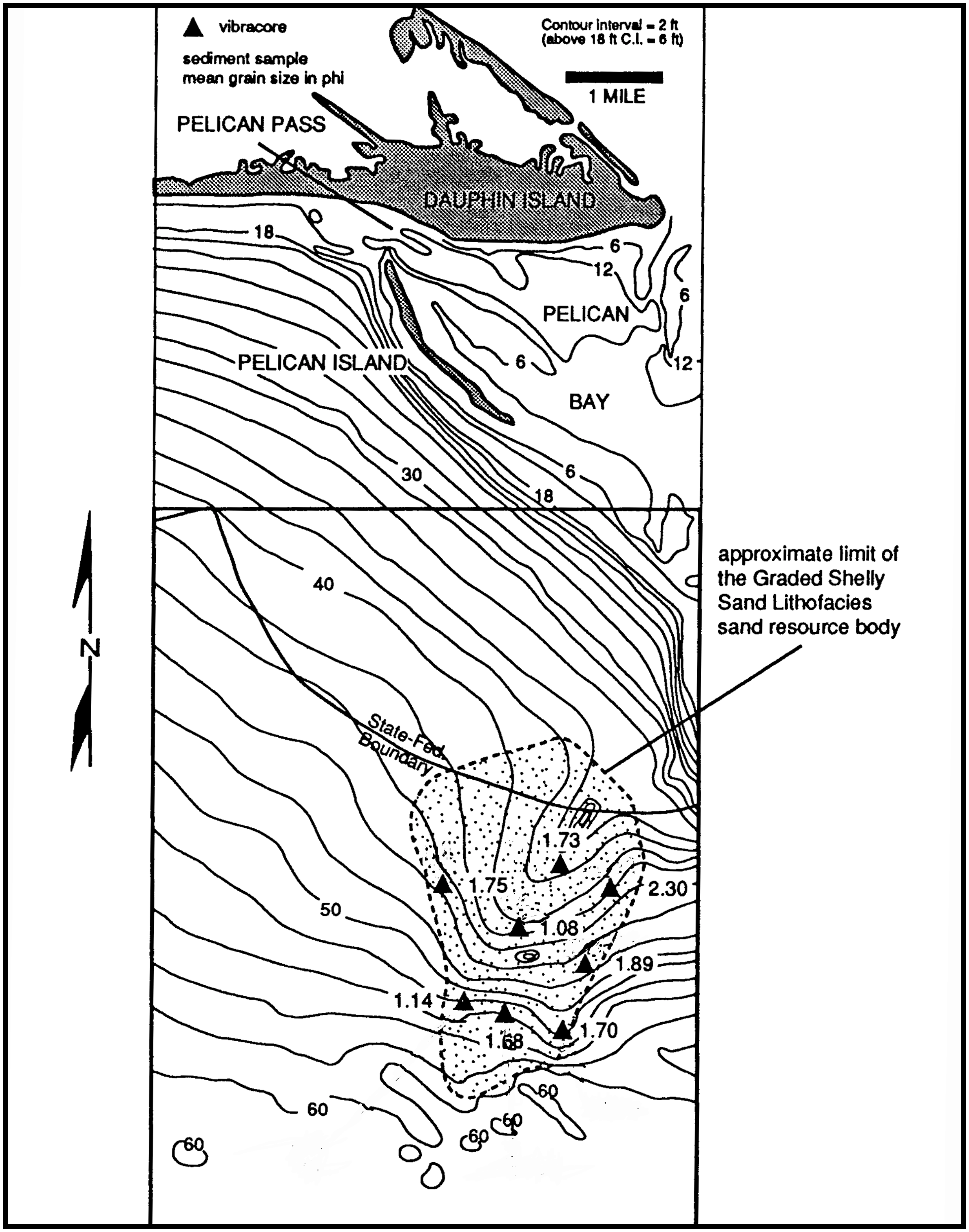

Figure 2-9. Map of the mean grain size of Graded Shelly Sand Lithofacies vibracore sediment samples 0.1 m below the sediment-water interface (from Hummell and Smith, 1996).

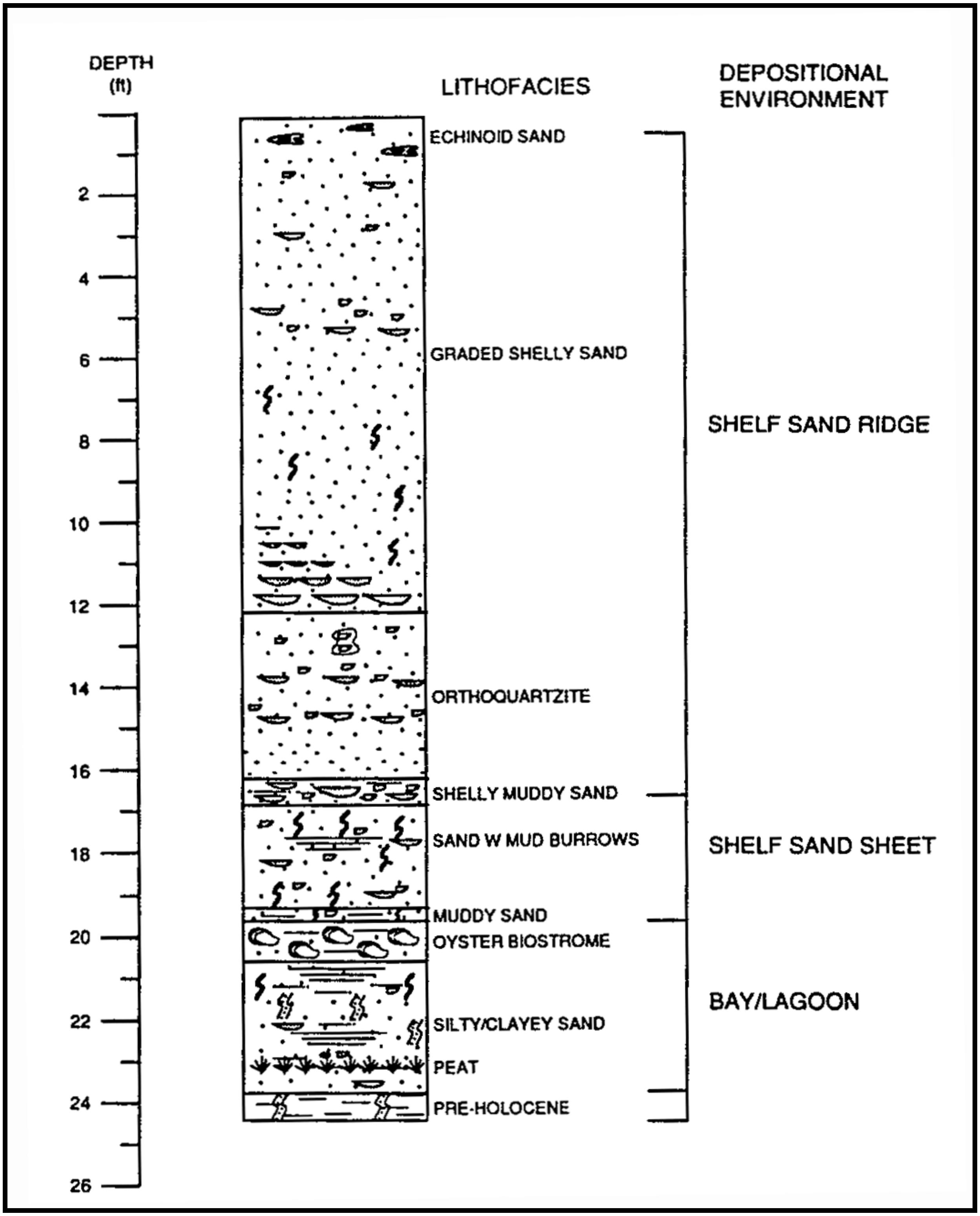

Figure 2-10. Generalized stratigraphic sequence of the Alabama EEZ study area (from Parker et al., 1997).

Sand Resource Area 1 is located on the eastern shelf south of Gulf Shores (Figures 1-1 and 2-11). The sand resource area in Federal waters encompasses approximately 4,200 ha (16 mi^2) and extends 5.5 to 12 km offshore. Water depths range from about 8.5 m (28 ft) MWL on the shallowest sand ridge to 14.5 m (48 ft) MWL at the offshore boundary. Maximum relief associated with sand ridges in the resource area is about 3 m. Based on vibracores and sediment samples collected by Parker et al. (1997), the entire resource area consists of medium- to fine-grained sand, with an average grain size of 0.25 mm. Sediment samples from vibracores contain about 97% sand. Sand deposit thickness ranges from 1 to 4.25 m (3 to 14 ft), with thickest sequences occurring over the ridges (Figure 2-12). Hummell (1999) estimates that the volume of sand suitable for beach replenishment in Area 1 is approximately 130 MCM. Sediment overfill ratios were calculated for each of the shoreline retreat zones based on sand resource area sediment characteristics versus beach sediment characteristics. For Perdido Pass, Parker et al. (1997) estimate that about 210,000 m^3 of beach fill would be required from Area 1 to restore the beach back to its original condition in 1955 (1.75 overfill ratio). For the beach south of Little Lagoon, a sand volume of 160,000 m^3 would be required (4.0 overfill ratio) to restore the beach to 1955 conditions.

Sand Resource Area 2 is located south of Little Lagoon Pass, extending from about 5.5 to 15.5 km offshore. The sand resource area encompasses approximately 7,400 ha (28.5 mi^2), and water depths range from about 10 to 18 m (33 to 60 ft; Figure 2-13) MWL. Parker et al. (1997) identify prominent sand ridges in the sand resource area that have relief ranging from 2 to 3.7 m (6 to 12 ft). Although sand quality is similar to that of Resource Area 1, sand deposits associated with shoals are noticeably thinner. Average mean grain size of the sand deposit is 0.27 mm, and sand content averages about 97%. Average sand thickness in the northern portion of the sand resource area is about 2 m (Figure 2-14), but sand thickness increases substantially in an offshore direction. Overall, Sand Resource Area 2 contains about 190 MCM of beach-quality sand (Hummell, 1999). The overfill ratios for beach replenishment sites at Perdido Pass and Little Lagoon are very similar to those identified for Area 1 (1.7 and 3.25, respectively). As such, the quantity of sand required to replenish these beaches would be about 155,000 m^3 and 100,000 m^3, respectively.

Sand Resource Area 3 is located offshore the western Morgan Peninsula, approximately 13 km east of Main Pass (Figures 1-1 and 2-15). It extends from the State-Federal boundary (about 5 km from the shoreline) 7 km seaward to around the 18-m depth contour and includes about 6,800 ha (26 mi^2) of seafloor (Parker et al., 1997). Water depths range from 8.5 to 18 m (28 to 60 ft) MWL, and a large northeast-southwest oriented shoal dominates seafloor morphology. This feature has almost 6 m of relief, and several individual sand ridges (1 to 2.5 m relief) are superimposed on the shoal and oriented in a direction perpendicular to its leading edge. Similar to Areas 1 and 2, sediment samples document an extensive medium- to fine-grained sand deposit. Sand content averages 96% and average mean grain size is 0.24 mm. According to Parker et al. (1997), average sand thickness in the area was difficult to determine because most cores did not penetrate the entire Holocene sequence. However, average sand thickness is greater than 3 m and may be as thick as 5 m in certain areas. Greatest sand thickness is associated with the main shoal and sand ridges, where sand is typically 3.5 to 4.5 m (12 to 15 ft) thick (Table 2-1; Figure 2-16). Based on core data from Parker et al. (1997) and Hummell (1999), Area 3 has the potential to provide approximately 245 MCM of beach-quality sand for beach replenishment. Calculated beach overfill ratios were similar but slightly greater than those identified for Area 2. As such, the volume of sand needed to restore the eroding shoreline downdrift of Perdido Pass to its 1995 position is about 175,000 m^3. For the shoreline erosion area downdrift of Little Lagoon Pass, the sand volume requirements would be about 110,000 m^3.

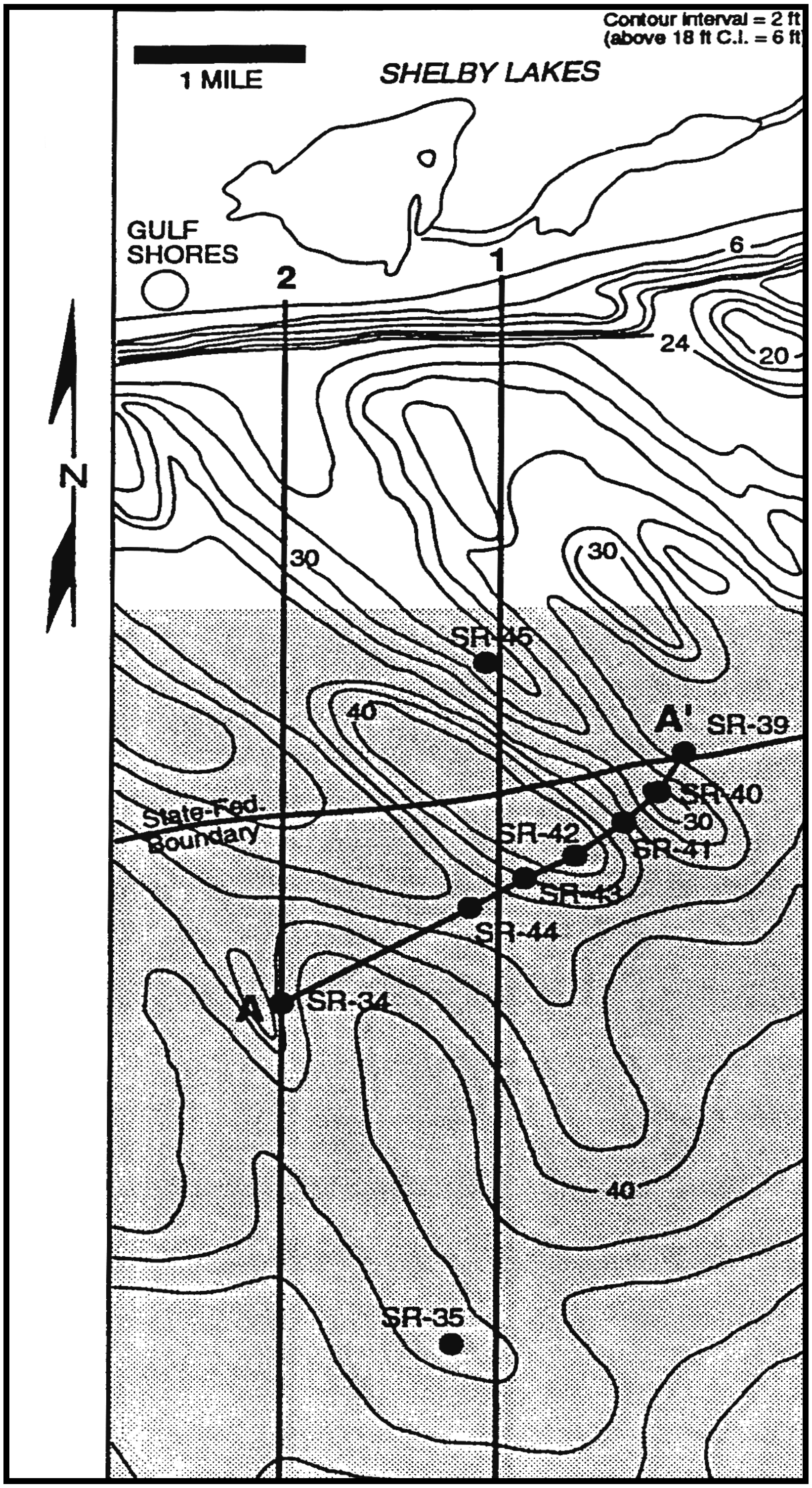

Figure 2-11. Map of the Sand Resource Area 1 (shaded area) showing location of cross section (A-A′ and bathymetric profiles (1 and 2) (from Parker et al., 1997).

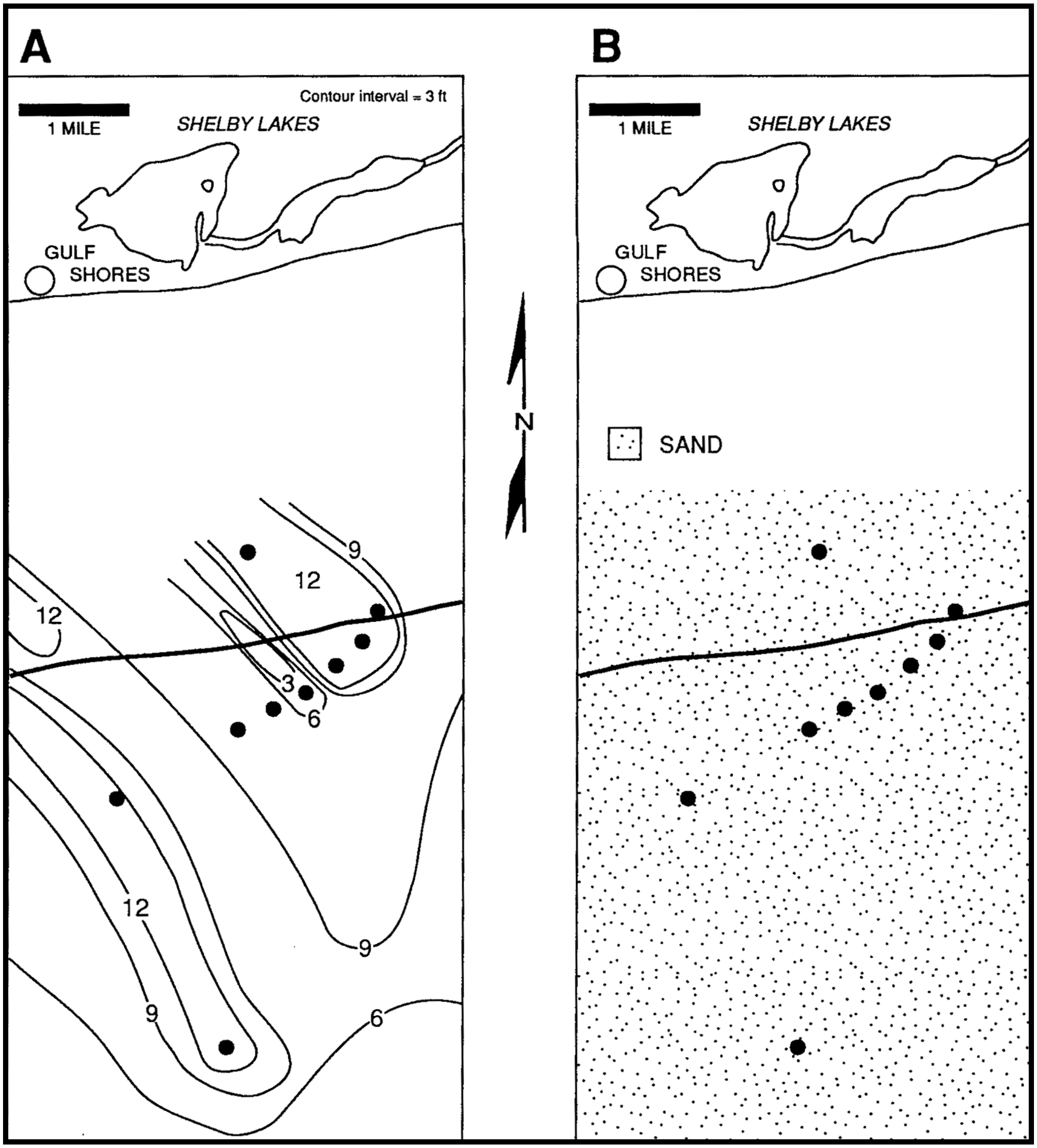

Figure 2-12. Sand isopach (A) and surface sediment texture (B) maps for Sand Resource Area 1 (from Parker et al., 1997).

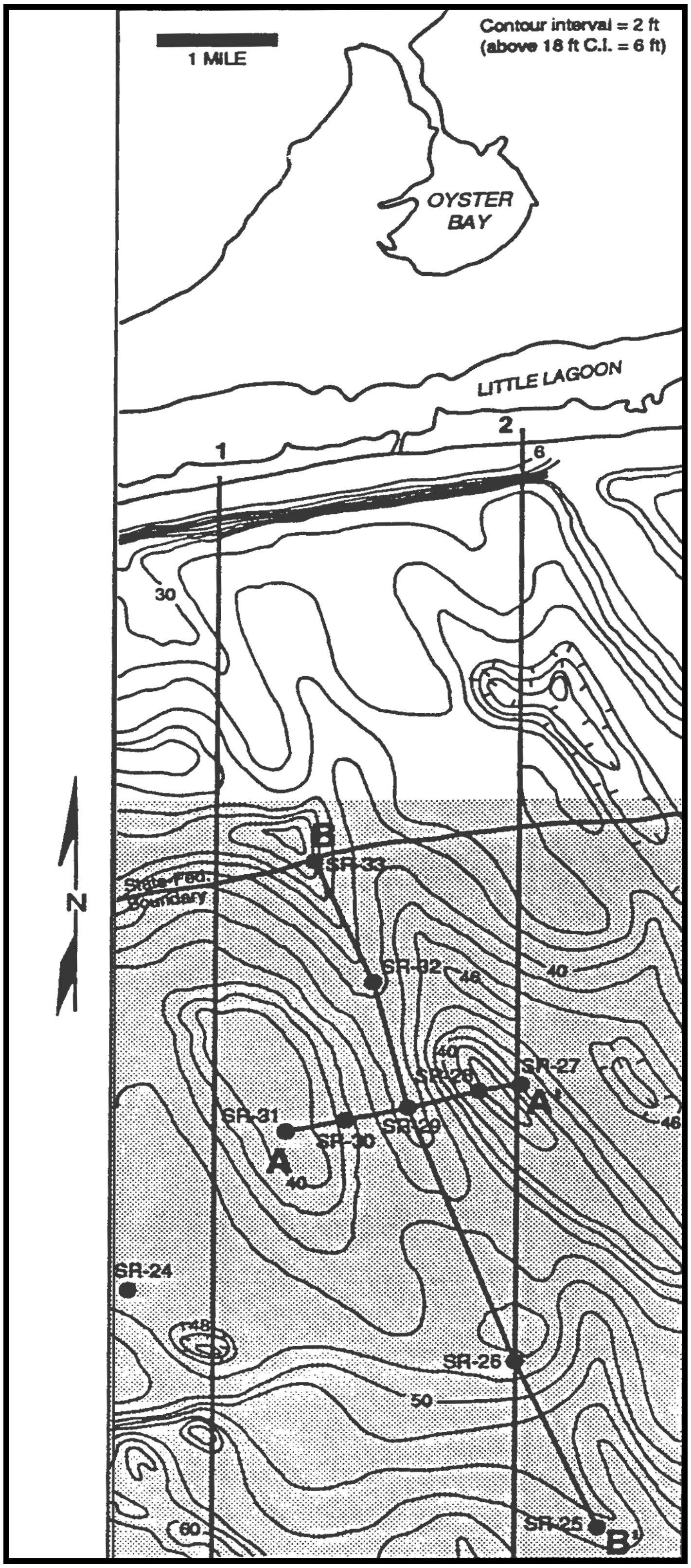

Figure 2-13. Map of Sand Resource Area 2 (shaded area) showing location of cross sections (A-A′) and (B-B′) and bathymetric profiles (1 and 2) (from Parker et al., 1997).

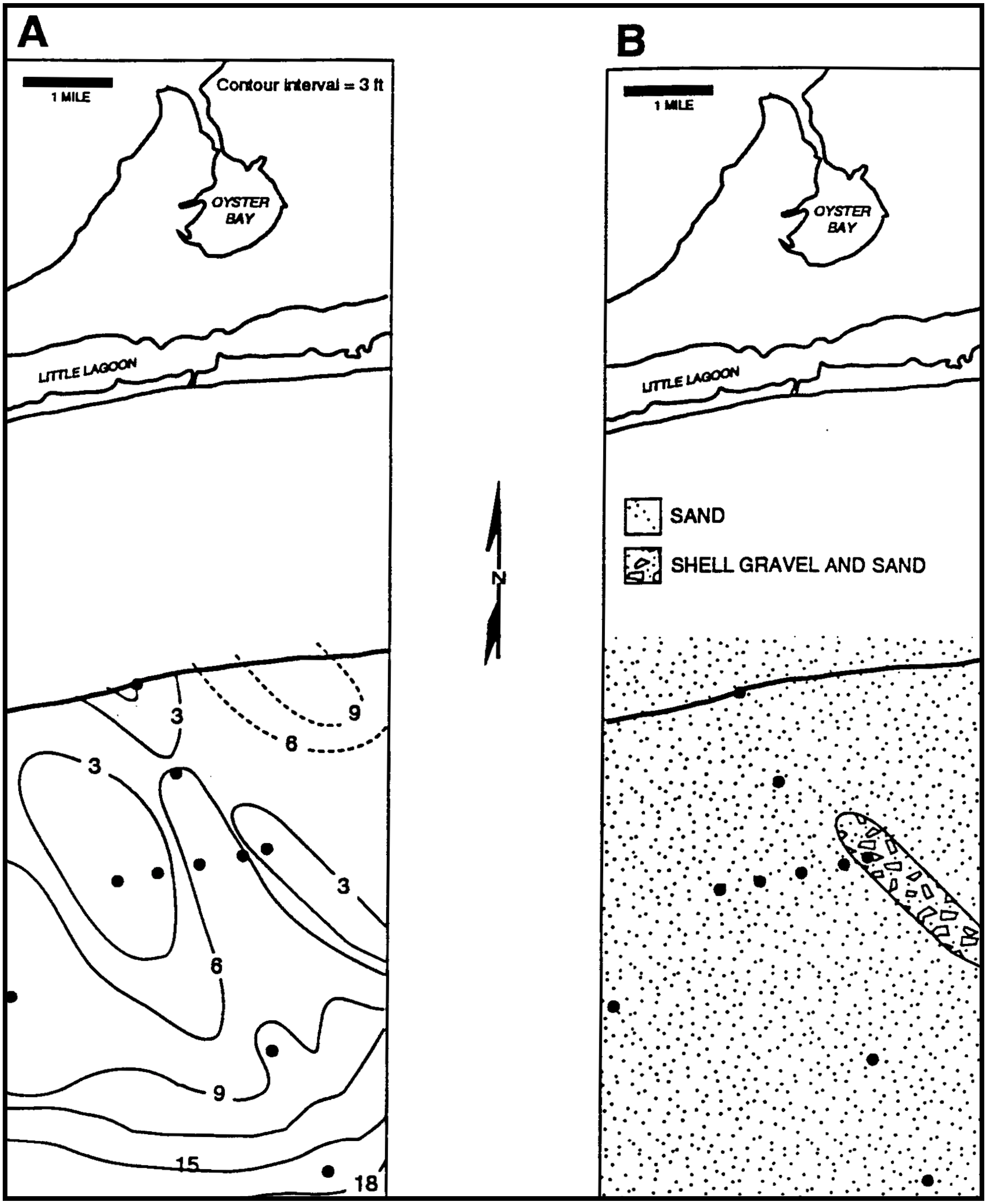

Figure 2-14. Sand isopach (A) and surface sediment type (B) for Sand Resource Area 2 (from Parker et al., 1997).

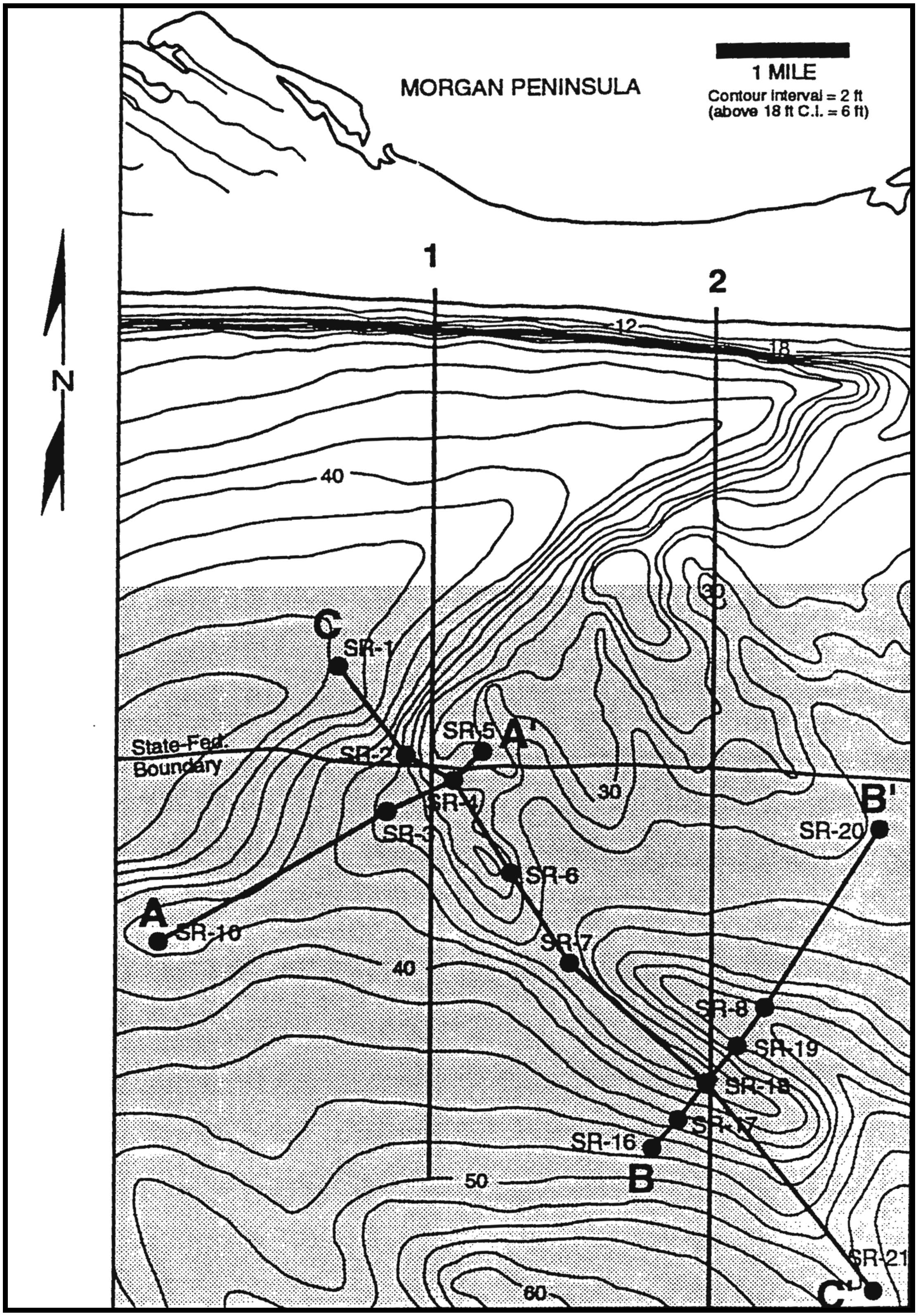

Figure 2-15. Map of Sand Resource Area 3 (shaded area) showing location of cross sections (A-A′, B-B′, and C-C′) and bathymetric profiles (1 and 2) (from Parker et al., 1997).

Table 2-1. Sand resource area characteristics (Parker et al., 1997; Hummell, 1999).							
Sand Resource Area	Distance from Shore (km)	Water Depth (m)	Seafloor Area (ha)	Mean Grain Size (mm)	Sand Content (%)	Average Sand Thickness (m)	Sand Volume (MCM)
1	5.5 to 12	8.5 to 14.5	4,200	0.25	97	1 to 4.25	130
2	5.5 to 15.5	10 to 18	7,400	0.27	97	2	190
3	5 to 7	8.5 to 18	6,800	0.24	96	3 to 5	245
4	8.5 to 16	18	400 *	0.35 *	96 *	3.0 *	12 *
5	6.5 to 12	12 to 18	3,300	0.25	90	2	60
* - Characteristics for GSA shelly sand resource site within Resource Area 4 (see Figure 2-9).							

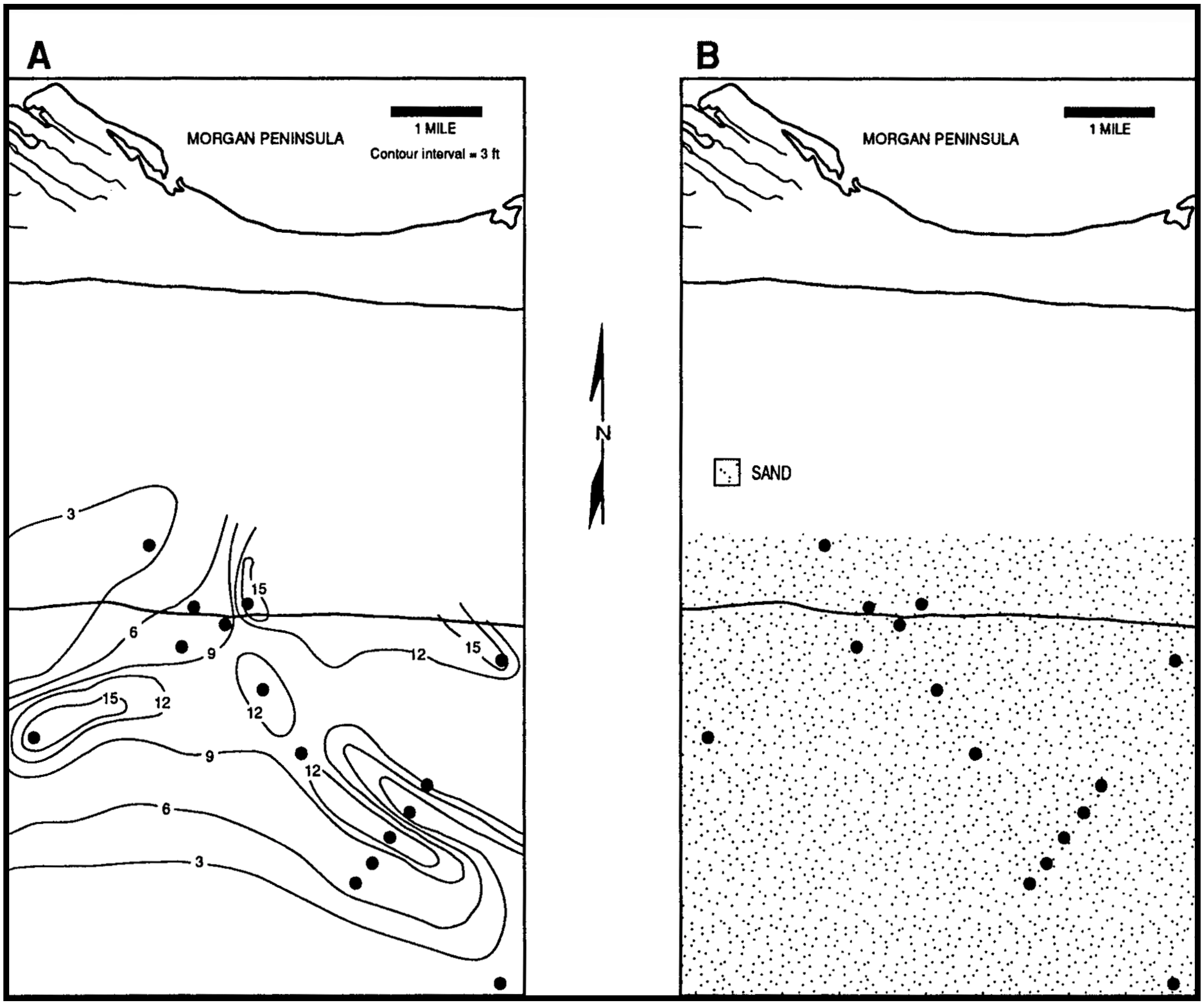

Figure 2-16. Sand isopach (A) and surface sediment texture (B) maps for Sand Resource Area 3 (from Parker et al., 1997).

West of Main Pass, Sand Resource Area 4 is located approximately 8.5 km south of eastern Dauphin Island adjacent to the western margin of the ebb-tidal delta for Main Pass (Figures 1-1 and 2-17). The seaward extent of Resource Area 4 is about 16 km offshore in 18-m (60-ft) MWL water depth, for a total seafloor area of about 7,700 ha (30 mi^2). Little relief exists in this sand resource area except for a small rise in elevation in the southeastern quadrant. Although Parker et al. (1993, 1997) completed the original data collection and analysis for this area, Hummell and Smith (1995, 1996) augmented these data with additional vibracores and foundation borings. Unlike eastern shelf sand resource areas, sediments in Sand Resource Area 4 consist of mud and muddy sand ebb-tidal delta and shelf deposits, and shelf sand ridge sands (Hummell and Smith, 1996). Although all of Resource Area 4 is influence by fine-grained deposition from Mobile Bay, Hummell and Smith (1995, 1996) were able to delineate a sand deposit in the northeast corner of the Federal sand resource area. Figure 2-18 illustrates surface sediment characteristics in Area 4; the Graded Shelly Sand lithofacies cluster of points denotes the location of the resource site. Average mean grain size for this area is about 0.35 mm, and sand thickness averages about 3.0 m. The sand deposit is in 12- to 16-m (39- to 53-ft) water depth, it increases in thickness to the south, and it grades into fine-grained facies on all sides (Hummell and Smith, 1996). Hummell and Smith estimated that this sand resource body contains approximately 12 MCM of compatible beach sand (about 97% sand), more than enough to suit the needs of eastern Dauphin Island (1.8 MCM; Table 2-1).

Area 5 is the westernmost sand resource site in the study area, occurring seaward of the western end of Dauphin Island in approximately 12- to 18-m (39- to 60-ft) MWL water depth (Figures 1-1 and 2-19). The sand resource site extends from the State-Federal boundary (about 6.5 km offshore) to approximately 12 km offshore Petit Bois Pass. The area of coverage is about 3,300 ha (12.5 mi^2), the smallest of any of the five sand resource areas. Seafloor topography in Area 5 is characterized by one large ridge with a relief of about 3 m (Parker et al., 1997). Surface sediment samples and vibracores identified a medium-to-fine sand resource area with an average mean grain size of 0.25 mm. Average sand content was about 90% (Parker et al., 1997). Sand thickness averages approximately 2 m (7 ft), but the exact thickness of the sand deposit was difficult to determine because none of the cores penetrated pre-Holocene sediment (Figure 2-20; Table 2-1; Parker et al., 1997). The thickness of sand increases offshore but remains fairly constant over the ridge. Parker et al. (1997) estimate that 60 MCM of sand is available for beach replenishment. However, smaller mean grain size relative to beach sand on eastern Dauphin Island results in a larger volume of fill needed to mitigate erosion trends since 1955. Parker et al. (1997) estimate that 2.3 MCM are required to restore Dauphin Island.

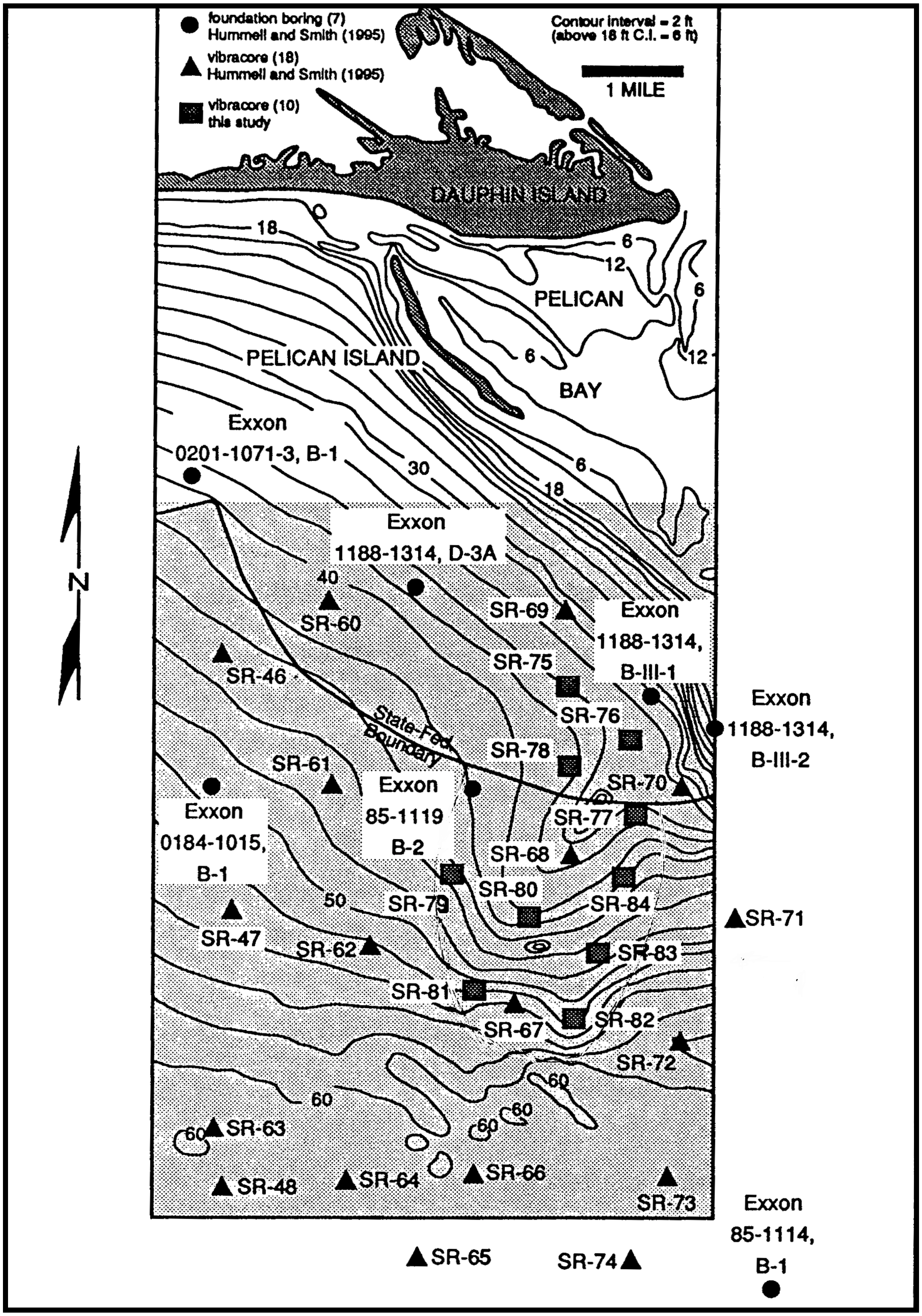

Figure 2-17. Map of Sand Resource Area 4 showing location of vibracores and foundation borings (from Hummell and Smith, 1996).

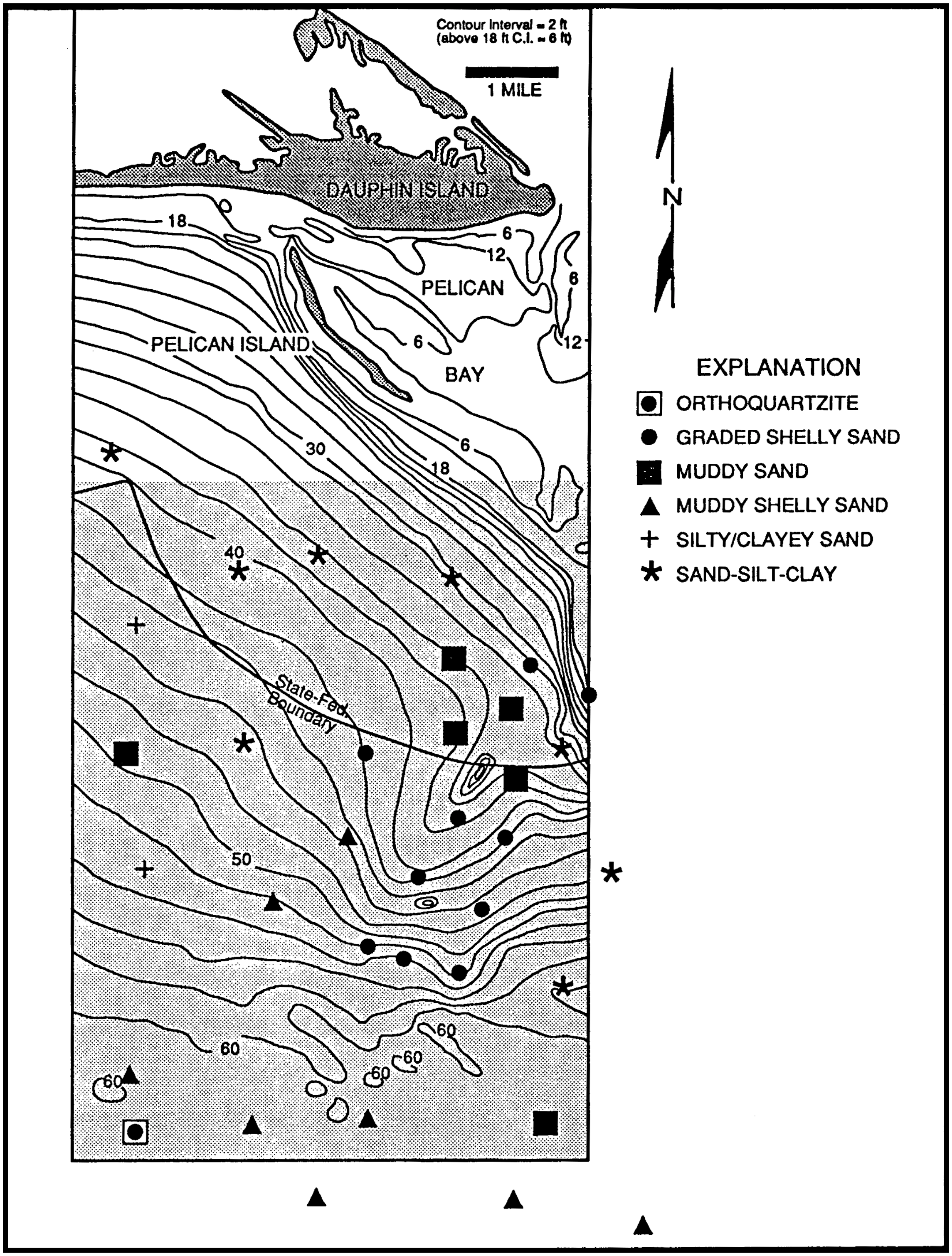

Figure 2-18. Surface facies distribution in Sand Resource Area 4 (from Hummell and Smith, 1996).

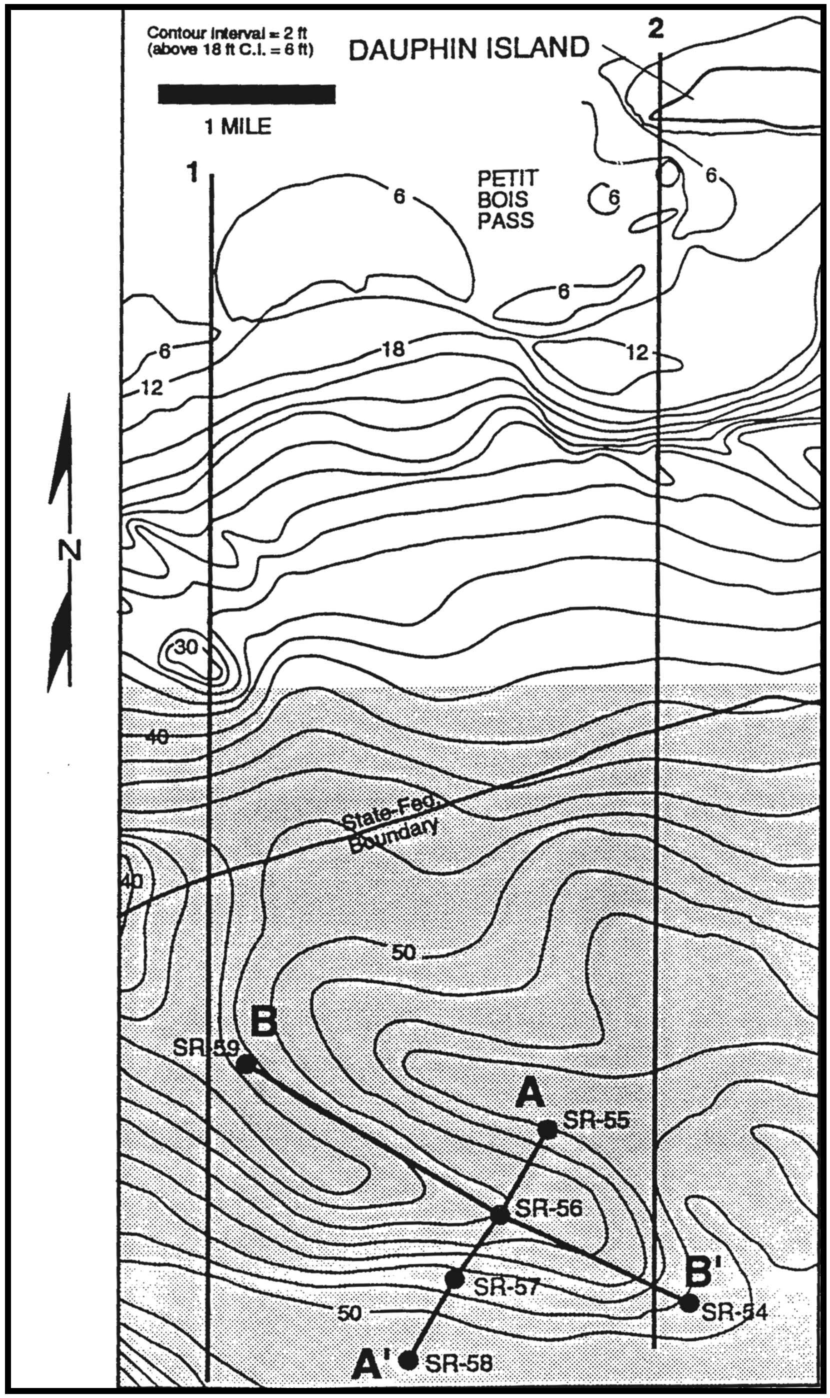

Figure 2-19. Map of Sand Resource Area 5 (shaded area) showing location of cross sections (A-A′ and B-B′) and bathymetric profiles (1 and 2) (from Parker et al., 1997).

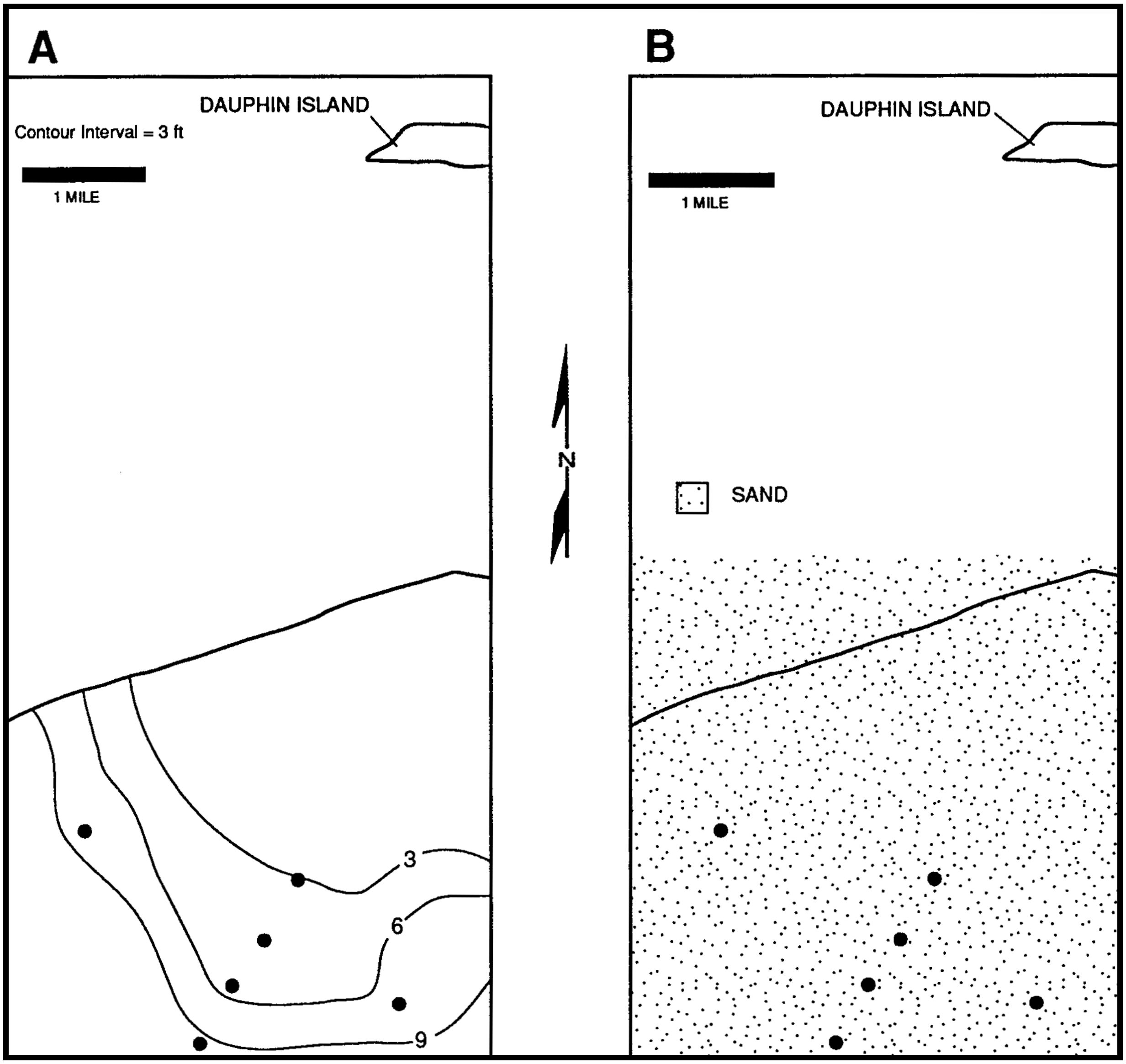

Figure 2-20. Sand isopach (A) and surface sediment texture (B) maps for Sand Resource Area 5 (from Parker et al., 1997).

2.2 CIRCULATION AND PHYSICAL OCEANOGRAPHY

Review of previously-published articles suggest circulation patterns in the offshore sand resource areas of Alabama result primarily from four dominant processes. These processes are wind-driven flow, tidal flow, buoyancy (or density)-driven flow, and influences of the Gulf Loop Current. Ocean currents at the sites display significant spatial and temporal variability, resulting from the relative strength of each of the forcing mechanisms. Total currents observed at any time (or location) typically are due to the sum responses of the water column to each of the individual forcing mechanisms mentioned above. There are interrelationships (or feedback responses) between different components that further complicate a description of these individual processes. The following review of literature will attempt to describe these processes, and how the circulation offshore of Alabama is affected by each component.

2.2.1 Waves and Wave-Generated Currents

The interaction of wind with the water surface generates waves. Once wind waves are generated, the forces of gravity, and to a lesser extent surface tension, allow waves to travel long distances across the sea surface. Waves are usually present at the shoreline because the sea surface is vast, winds are prevalent, and waves can travel long distances. Waves are primarily responsible for sediment transport in the nearshore zone and for subsequent shoreline change; therefore, waves are of fundamental interest to determine the potential effects of offshore sand mining on beach erosion.

As waves enter the nearshore zone, varying seafloor morphology causes the characteristics of waves (e.g., height and direction of travel) to change. As waves enter shallow water, their height increases (shoaling), and the direction of travel bends toward the coast so that wave crests become more parallel to the shoreline (refraction). As waves approach shore, shoaling and wavelength modifications overcome dissipation effects and cause wave height to increase and waves to steepen. Eventually wave steepness causes the wave to become unstable and break, which dissipates wave energy. Energy also is distributed along a wave crest by a process called wave diffraction. Together, wave shoaling, refraction, diffraction, and breaking can focus wave energy on particular areas, depending upon the characteristics of nearshore bathymetry.

General characteristics of waves that impact the Alabama Coast are as follows. Waves are generated by winds in the Gulf of Mexico. In general, there are seasonal variations in wave climate governed by seasonal characteristics of wind. Summer months (typically considered May through October) are characterized by relatively calm winds and low-energy waves, while winter months (typically considered December through April) are characterized by a more energetic wind and wave climate. Sporadic storms, such as hurricanes and cold fronts, generate the largest waves that impact the Alabama Coast.

More specific information about the waves impacting the Alabama Coast is provided in the published literature (although existing literature discussing waves and wave-generated currents is limited). For instance, Bedford and Lee (1994) collected short-term wave data in August and September 1989, approximately 760 m offshore of Dauphin Island and west of the Mobile ship channel. These authors deployed a pressure and current (PUV) sensor at a water depth of approximately 6 m. The pressure sensor was inoperative leaving only directional current measurements. Wave height was interpreted, therefore, from available data using linear wave theory. Spectral analysis showed that wave periods ranged from 3 to 10 sec, with the maximum wave energy associated with a peak wave period of 5.8 sec. Significant wave heights were approximately 80 cm. Although wave direction was not resolved well, given the failure of the pressure sensor, it was determined that waves were directed almost due north.

Another set of wave and current data in this region was collected by the USACE using wave gauges and near-bottom electromagnetic current meters as part of a monitoring program of nearshore dredged material disposal sites off the Alabama Coast. McGehee et al. (1994) provide details on the gauges and data collection procedures. Two wave gauges were installed by the National Data Buoy Center (NDBC) for that study between 1987 and 1990. The two wave gauges were deployed 1.3 and 2.6 km offshore.

Douglass et al. (1995) evaluated these long-term wave measurements, along with nearshore current measurements collected by the USACE in the vicinity of the disposal sites, to determine what mechanisms are responsible for long-term landward migration of large submerged sand bodies. These authors concluded that waves in this region provide the dominant mechanism responsible for moving Alabama berms persistently landward. Wave-driven sediment transport is due to faster landward current speeds under wave crests that are characteristic of shallow water, nonlinear waves. It was concluded that wave processes dominate other potential sediment transport processes, such as mean currents and short-term storms.

From more of a geological perspective, McBride and Byrnes (1995) performed a detailed study of nearshore sediment characteristics in this region. These authors concluded that ocean and wave-generated currents produce shelf and shoreface sand ridges in the region of southwestern Alabama/western Florida. This finding is consistent with that of Douglass et al. (1995), who concluded that waves provide a significant sediment transport mechanism offshore of Alabama.

2.2.2 Wind-Generated Currents

The meteorological climate for the northeastern Gulf of Mexico (NEGOM) can be separated into two distinct seasonal periods: summer and winter (Clarke, 1994; Schroeder et al., 1994). Each of these periods is dominated by different types of air masses. The summer period is defined between May (late spring) through early fall (October), and it is characterized by stable high pressure air resulting from the more-northerly position of the Atlantic high pressure zone ('Bermuda High'). During this period, high pressure off the Atlantic coast brings relatively mild tropical air into the region, resulting in typically weak southerly winds. During the winter period, defined typically as December through April, the southern migration of the Atlantic high pressure zone allows polar air to intrude into the region, bringing with it Arctic frontal systems of cold, dry air. Northerly winds are more common during this period. These polar air intrusions occur at time scales of 3 to 10 days, and they result in more energetic air-sea disturbances. More vigorous vertical mixing of the water column is possible during the winter period.

The effect of these winds on nearshore barotropic currents can be exaggerated due to the presence of the shoreline, which creates an impermeable flow boundary, blocking typical Ekman response of the water column to wind forcing (Clarke, 1994). The result can be stronger response of the water column to wind forcing in nearshore zones than would be expected in deeper water. Lewis and Reid (1985) describe the along-shelf flow to be correlated to along-shelf winds. Reid (1994) stated that the longshore reversals in near-shore current directions (on subtidal time scales of order 3 to 10 days) observed during the Louisiana-Texas Shelf Physical Oceanography Program (LATEX; along the Louisiana-Texas coast west of the Mississippi River) result from similar reversals in the longshore wind component. For the Alabama locations, this suggests that wind-driven currents are likely strongest during the October to April period, when they are oriented approximately in the direction of the longshore wind component. Wind-driven currents in the summer months would be expected to be weaker.

Upwelling and downwelling processes may have an important effect on the spatial variability of nearshore barotropic currents. These processes produce a two-dimensional cross-shore circulation cell. In the upwelling case, surface waters are driven offshore by a longshore wind component that blows from the west with resulting bottom currents pulled shoreward to complete the circulation cell. Downwelling occurs when the longshore component drives surface flow onshore; bottom flow then retreats offshore. These processes can be modified significantly by density gradients in the cross-shore direction.

Storm events, typically hurricanes, passing the region can generate anomalous currents in the nearshore region. Measurements of currents during Hurricane Chantal (Douglass et al., 1995) show a modification to the mean bottom currents, increasing in magnitude to approximately 30 cm/sec from a pre-storm mean of approximately 10 cm/sec. Hurricane Chantal was considered a mild event (Category I hurricane) and passed about 800 km to the west of Alabama. Hence, these results probably do not adequately describe the expected local response to a more severe storm. Murray (1970) presented current observations obtained along the inner shelf (approximately 90 m offshore in 6.3-m water depth) offshore of Pensacola during the passage of Hurricane Camille. The eye of Camille passed approximately 160 km to the west of the mooring. The current meter collected readings exceeding 160 cm/sec (wave orbital velocities had been removed from the record) before malfunctioning. The winds had not yet reached peak speed at the time of malfunction; extrapolating the current signal suggests the current speeds during the storm may have exceeded 200 cm/sec. These high speed flow responses to storm wind forcing were oriented in the direction of the wind stress vector; at that time, the wind was blowing out of the east. When the wind rotated to the southeast, blowing toward the shore, an offshore-directed flow was observed along the bottom. The bottom return flow in an offshore direction was produced in response to storm-surge setup along the shore and the need to balance the shore-normal pressure gradient.

2.2.3 Tidal Currents

Tidal currents in the NEGOM are strongly diurnal, dominated by the O1 (period of 25.82 hours) and K1 (period of 23.93 hours) tidal constituents (Clarke, 1994). Water elevation variations due to the tides average 45 to 60 cm, although the maximum range (tropic tides) can approach 80 cm while the minimum (equatorial tides) can be near-zero (Schroeder et al., 1994). Currents resulting from tidal elevation variations are assumed to vary along the same order.

Seim et al. (1987) found that tides on the Alabama-Mississippi inner shelf have a major axis oriented perpendicular to the shoreline with a shore-normal mean amplitude of approximately 6 to 8 cm/sec and a minor axis in the alongshore direction with a mean amplitude of 4 cm/sec. The tidal ellipses rotate in a clockwise sense on the shelf (Kinoshita and Noble, 1995).

Tidal currents on the inner shelf near the entrance to Mobile Bay are influenced by the ebb-tidal jet and, hence, dominated by the southward ebb flow from the Bay. However, current measurements made just west of the lighthouse at the entrance (near Sand Resource Area 4) show that the dominant tidal component is in the alongshore direction (Douglass et al., 1995), with a relatively weaker cross-shore component.

2.2.4 Effects of Density

Density-driven (baroclinic) currents on the continental shelf can be important in determining spatial variability of flow. Fresh water discharged from Mobile Bay is significant. This input of low density water creates a density gradient in the cross-shore direction. This gradient can result in an alongshore movement where the direction of flow will be to the right of the pressure gradient (Blanton, 1994). For Alabama, this suggests a baroclinic flow to the west when near-shore density gradients are present.

The structure of the near-shore density field can vary seasonally. In summer, a strong vertical stratification develops due to surface heating, as well as decreased vertical mixing (winds are milder). In winter, reduced heating and more vigorous vertical mixing tend to weaken the vertical stratification and produce a horizontal gradient (Clarke, 1994). Hence, the strength of the alongshore flow due to cross-shore density gradients is assumed to vary on a seasonal basis, with baroclinic flows likely strongest in winter.

Mobile Bay has the fourth-largest freshwater discharge in the United States (Morisawa, 1968), with an average annual mean of 1,850 m^3/sec. Schroeder et al. (1994) states average mean discharge is more like 2,200 m^3/sec. The peak discharge occurs in late winter/early spring and can be as high as 16,000 m^3/sec; the minimum discharge is in autumn when the discharge can average 500 m^3/sec (Stumpf et al., 1993). The result is a freshwater plume exiting Mobile Bay that persists for much of the year (Gelfenbaum and Stumpf, 1993). The plume is defined as a thin veneer (1 to 2 m thick) of fresh water overlying more saline ambient water (Gelfenbaum, 1994).

Schroeder et al. (1994) describes the plume as advecting to the east; however, no physical explanation of why this occurs was given. Other studies (Stumpf et al., 1993, Gelfenbaum and Stumpf, 1993) suggest the plume responds rapidly to local wind stress, hence the direction of the plume upon exit from the Bay likely depends on the direction of the alongshore wind stress component.

Gelfenbaum and Stumpf (1993) presented observations of current and waves collected on both sides of a well-developed buoyant plume front near the mouth of Mobile Bay. Measurements collected in ambient water were compared to those collected within the plume. Results indicated flow within the buoyant plume was largely decoupled from the ambient flow; the ambient flow moved around and beneath the plume. In addition, the plume created a buffer above the ambient water; this buffer retarded vertical mixing as well as attenuated surface waves. Surface wave heights within the plume were lower than those measured outside the plume. Also, wave periods within the plume were shorter than those detected outside the plume. This implies that the plume modifies the local wave field, and may modify sediment transport processes beneath it.

2.2.5 Gulf Loop Current

The Gulf Loop Current has been studied extensively in past several decades, and it is a major influence on deep basin circulation. The Gulf Loop Current can impinge upon the shelf and significantly influence flow behavior on the NEGOM shelf. Kelly (1994) reported that intrusions of the Gulf Loop Current on the shelf occurs approximately 44% of the time. Intrusions were defined as observations of the warm-core ring itself, or filaments of the Gulf Loop Current. While these intrusions have significant influences on mid- and outer-shelf flow patterns, there was no mention of intrusions into the nearshore zone. There does not appear to be published evidence indicating the Gulf Loop Current has significant effect on the upper continental shelf.

2.2.6 Nearshore Sediment Transport

Nearshore sediment transport is a complex process, which governs erosion and accretion of beaches. Sediment is moved alongshore and cross-shore (on and offshore) by physical coastal processes, such as wind, waves, tides, currents, and sea-level rise. The time scales of sediment transport and shoreline change vary from the initial formation of headlands and coasts on geologic time scales (thousands of years) to severe coastal erosion over a few days or hours during tropical storms and hurricanes.

In addition to physical coastal processes, sediment transport patterns are dependent upon the characteristics and supply of sediment. Grain size is the most important characteristic of the sediment. The quantity of sediment moved is inversely proportional to its grain size. Sediment transport rates decrease with increasing grain size, because heavier sediment requires more time and energy to be transported. Sediment density, durability, and shape also affect transport rates. In addition, the supply of sediment governs sediment transport rates, because transport rates are reduced where sediment is in short supply.

When waves break at an angle to the beach, alongshore-directed currents are generated, capable of lifting and moving sediment along the coast. For example, waves approaching the Gulf Shores shoreline from the east tend to move sand alongshore from east-to-west towards Main Pass. Because wave direction changes frequently, sand is moved back-and-forth along the beach. On an annual basis, however, there typically is a dominant wave direction that occurs most frequently on seasonal time scales.

Past work regarding longshore transport rates for Dauphin Island and the Morgan Peninsula is limited. According to Parker (1990), wave-generated longshore currents have the most apparent effect on sediment transport. Although it is generally accepted that the typical east-to-west currents dominate beach transport processes, the amount of sediment entrained in the littoral system along the Alabama barrier islands is not known with confidence. The only known quantitative estimates of littoral transport rates were calculated by the U.S. Army Corps of Engineers. Garcia (1977) determined that the total net longshore sediment transport rate at Dauphin Island was approximately 196,000 yd^3/yr, and the U.S. Army Corps of Engineers (1955) estimated about 200,000 yd^3/yr of net littoral transport at Perdido Pass.

2.3 BIOLOGY

2.3.1 Benthic Environment

The following subsections provide summaries of the existing literature concerning the benthic environment, including infauna (Section 2.3.1.1) and epifauna and demersal ichthyofauna (Section 2.3.1.2), in and around the five sand resource areas. This information, along with the assessment of ecological conditions from the biological field surveys (see Section 6.0), provides the framework for the evaluation of potential effects of dredging on these organisms (Section 7.5).

2.3.1.1 Infauna

Previous infaunal studies in or near the sand resource areas include small-scale surveys (TechCon, Inc., 1980; Exxon Company, U.S.A., 1986; Barry A. Vittor & Associates, Inc., 1988; Continental Shelf Associates, Inc. and Barry A. Vittor & Associates, Inc., 1989) and regional surveys (Dames & Moore, 1979; Shaw et al., 1982; Harper, 1991). Organisms collected during these investigations consisted of members of the major invertebrate groups that commonly are found in sand bottom marine ecosystems, including crustaceans, echinoderms, mollusks, and polychaetous annelids. Generally, infaunal assemblages offshore Alabama tend to be numerically dominated by polychaetes (Shaw et al., 1982; Harper, 1991). Other conspicuous members of the infaunal community include amphipod crustaceans and bivalves. Seasonality is apparent in the overall abundance of infauna, with winter densities generally lower than during other seasons (Shaw et al., 1982; Barry A. Vittor & Associates, Inc., 1985; Harper, 1991).

Previous sampling efforts over broad areas of the northern Gulf of Mexico shelf have emphasized the importance of sediment type in determining infaunal community composition. Studies of the infauna of the Mississippi, Alabama, Florida Outer Continental Shelf (MAFLA OCS) by Dames & Moore (1979) revealed that inner shelf benthic habitats of the NEGOM can be described primarily on the basis of sediment texture and water depth. Shaw et al. (1982) surveyed infauna in the inner shelf area off Mississippi Sound, which included portions of Sand Resource Areas 4 and 5. This study is one of the most comprehensive historical surveys in the area, and describes distinct infaunal assemblages that are associated with mud, muddy sand, or sandy substrata within varied depth zones in shelf waters.

Based on a review of the studies cited above and other previous studies in the area, Barry A. Vittor & Associates, Inc. (1985) recognized four depth-related benthic habitats for infaunal communities in the region of the NEGOM: shallow beach habitat; inner shelf habitat; intermediate shelf habitat; and outer shelf habitat. Each of these habitats was further divided into sediment type (mud, sandy mud, muddy sand, or sand). Infaunal assemblage associations were recognized with each combination of water depth and substratum type. Cluster analysis revealed that infaunal taxa were closely tied to sediment type and texture (Figure 2-21).

The inner shelf habitat (4 to 20 m depth) of Barry A. Vittor & Associates, Inc. (1985) corresponds most closely with the location of the sand resource areas. Eight distinct infaunal assemblages were identified in this area. Three of these inner shelf assemblages exhibited narrow sediment texture preferences, while the other five assemblages showed transitional distributions (Figure 2-21). Muddy sand (50% to 90% sand) did not support a habitat-specific assemblage on the inner shelf, but instead was inhabited by transitional taxa that extended their range into areas characterized by other sediment types. Those assemblages that exhibited a narrow preference for a particular sediment texture were associated with mud, sandy mud, or sand. The mud (<20% sand) habitat assemblage was represented by the hemichordate *Balanoglossus* cf. *aurantiacus*, the polychaete *Paramphinome* sp. B, and the mollusks *Nassarius acutus* and *Utriculastra canaliculata*. The sandy mud (20% to 50% sand) habitat assemblage included the ophiuroids *Hemipholis elongata* and *Micropholis atra*, the bivalve *Nuculana concentrica*, and the crab *Pinnixa pearsei*.

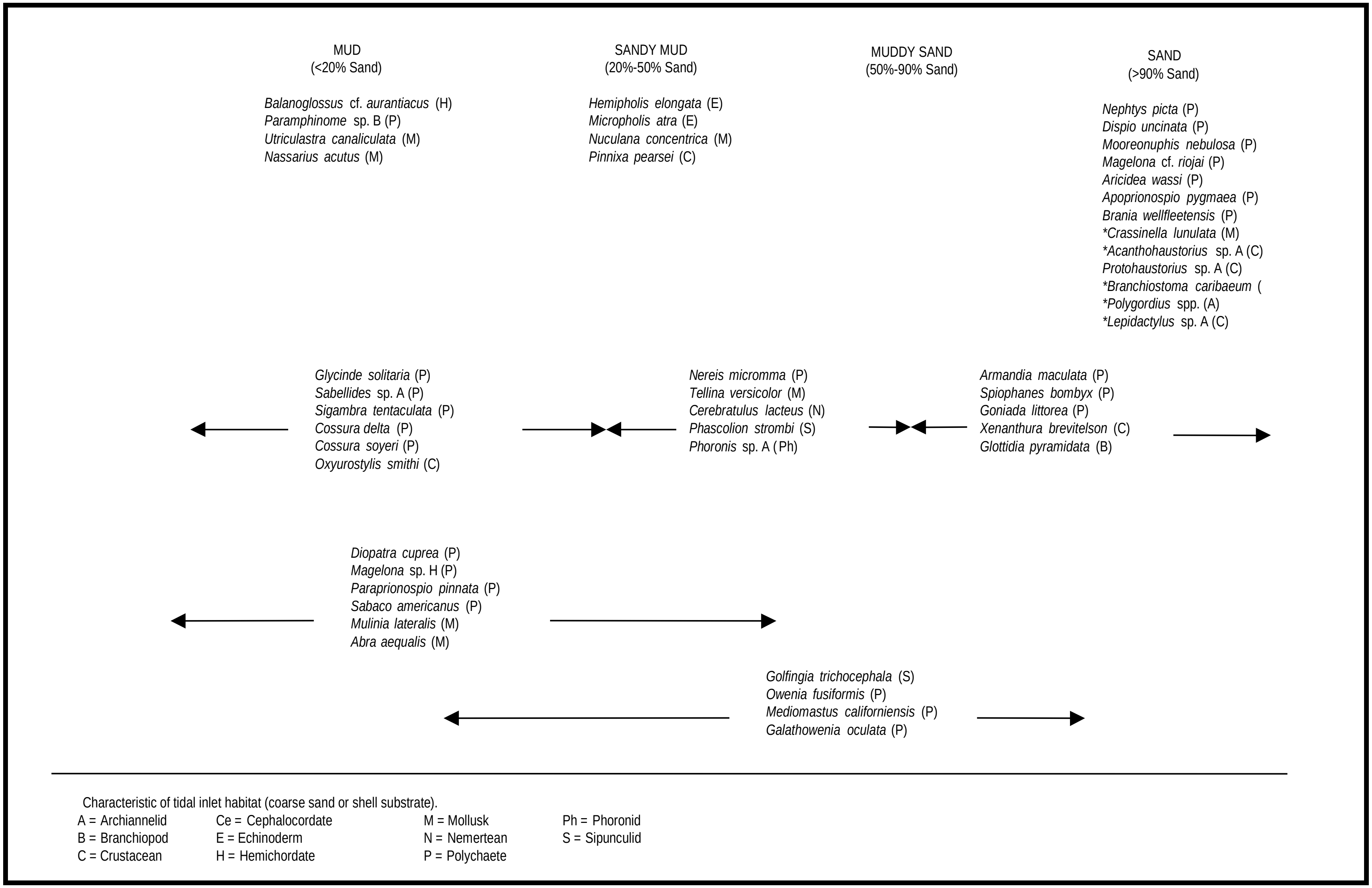

Figure 2-21. Infaunal assemblages associated with habitats on the inner continental shelf (<20 m depth) in the northeastern Gulf of Mexico study area (from Barry A. Vittor & Associates, Inc., 1985).

Inner shelf sand habitat (>90% sand) included amphipods of the genera *Acanthohaustorius*, *Protohaustorius*, and *Lepidactylus*, the archiannelid *Polygordius*, the lancelet *Branchiostoma caribaeum*, and a large number of polychaetes, including *Apoprionospio pygmaea*, *Aricidea wassi*, *Mooreonuphis nebulosa*, and *Nephtys picta* (Barry A. Vittor & Associates, Inc., 1985).

The Mississippi-Alabama Marine Ecosystems (MAME) study included sampling of infauna along three north-south transects in northern Gulf of Mexico shelf waters (Harper, 1991), and was the most recent large-scale shelf survey of sediment-inhabiting benthos. Infaunal densities were correlated with sediment particle size, with coarser sediments supporting higher densities. Inner stations of the De Soto Canyon and Mobile transects were located just within the southern edge of Sand Resource Areas 1 and 4, respectively. These two stations both were characterized by an infaunal assemblage associated with relatively coarse sediments, and included the amphipods *Ampelisca abdita* and *A. verrilli*, the bivalves *Parvilucina multilineata* and *Tellina versicolor*, the decapods *Euceramus praelongus* and *Spinocarcinus lobatus*, and various polychaetes, including *Aglaophamus verrilli, Mediomastus californiensis, Nereis micromma*, and *Spiophanes bombyx.*

The Geological Survey of Alabama reported benthic fauna sampled from various locations in Sand Resource Area 4 offshore Alabama (Hummell and Smith, 1995). In that study, about 82% of infaunal individuals sampled were unidentified polychaetous and oligochaetous annelids. Nearly 25% of the infauna collected consisted of a single taxon, the polychaete *Diopatra* sp. The second most abundant identified taxon was the rhynchocoel *Cerebratulus lacteus*, which contributed 6% of all organisms. Other identified taxa found in Area 4 included the echinoderm *Ophiolepis elegans* and the mollusks *Cerithium eburneum*, *N. concentrica*, and *Solen viridis*. The authors concluded that the assemblage was similar to that inhabiting the offshore mud habitat described by Shaw et al. (1982).

In addition to infaunal assemblages that exhibit narrow sediment texture preferences, regional surveys typically include other assemblages that show transitional distribution patterns (Barry A. Vittor & Associates, Inc., 1985). Several transitional species assemblages are commonly represented on the inner shelf habitat, each with affinities for broad ranges of sediment composition. These assemblages contain ubiquitous taxa, including the bivalve *Mulinia lateralis* and the polychaetes *Armandia maculata*, *Magelona* sp*.* H, *Mediomastus*, *Owenia fusiformis*, and *Paraprionospio pinnata* (Figure 2-21). These species are well adapted to burrowing and foraging in fine sediments.

Infaunal assemblages are comprised of species adapted to particular sedimentary habitats through differences in behavioral, morphological, physiological, and reproductive characteristics. Feeding is one of the behavioral aspects most closely related to sedimentary habitat (Rhoads, 1974). In general, habitats with coarse sediment and high water current velocities, where organic particles are maintained in suspension in the water column, favor the occurrence of suspension-feeding taxa that strain food particles from the water column. Coarse sediments also facilitate the feeding of carnivorous taxa that consume organisms occupying interstitial habitats (Fauchald and Jumars, 1979). At the other extreme, habitats with fine-textured sediments and little or no current are characterized by the deposition and accumulation of organic material, thereby favoring the occurrence of surface and subsurface deposit feeding taxa. In between these habitat extremes are a variety of habitat types that differ with respect to various combinations of sedimentary regime, depth, and hydrological factors, with each habitat type facilitating the existence of particular infaunal assemblages (Barry A. Vittor & Associates, Inc., 1985). An east-to-west transition of sedimentary regimes, from predominantly sands along the west Florida shelf to silts and clays along the Louisiana shelf, was evident during previous regional studies. Infaunal assemblages varied along this east-west gradient as well (Shaw et al., 1982; Barry A. Vittor & Associates, Inc., 1985).

The distribution and abundance of infaunal populations are influenced by factors other than sediment type. Results of previous studies also reflect the significance of local hydrology, with euryhaline taxa occurring in lower densities east of Mobile Bay (Barry A. Vittor & Associates, Inc., 1985). The increase in salinity toward the west Florida shelf, due to a diminishing influence of riverine discharge from Mobile Bay, produces a diverse array of stenohaline taxa, especially crustaceans. Freshwater intrusion is one of the major environmental factors that affect the study area, especially in spring, bringing both lower salinities and increased sedimentation in waters near Mobile Bay. Infaunal assemblages of the Alabama inner shelf typically include taxa characteristic of muddy estuarine habitats, especially opportunistic species that inhabit areas that most taxa cannot. These euryhaline species predominate in inner shelf habitats during periods of elevated river discharge, and include the polychaetes *P. pinnata* and *Mediomastus* (Continental Shelf Associates, Inc. and Barry A. Vittor & Associates, Inc., 1989). These and other transitional taxa are able to numerically dominate habitats that experience various perturbations, including siltation, low salinity, and low levels of dissolved oxygen (hypoxia). Some transitional taxa are among the initial colonizers of disturbed areas offshore Alabama (Shaw et al., 1982).

Hypoxia is known to occur in the offshore Alabama region, and may be caused by water column organic enrichment, by stagnation due to water column stratification, or by other large-scale hydrological factors. Although a natural occurrence, some investigators believe that the frequency of hypoxic episodes may be increasing due to human influences (Turner and Rabalais, 1994). Hypoxia may negatively affect the distribution and abundance of some infaunal assemblages. Persistent hypoxia may result in defaunation of nearshore benthic habitats. In general, infauna are more negatively affected by hypoxia than are nektonic taxa because of their relative lack of mobility. The major invertebrate groups that comprise benthic assemblages exhibit varied levels of tolerance to hypoxia, with polychaetes being the most tolerant group, followed by bivalves. Crustaceans and echinoderms seem to be the least tolerant of hypoxic conditions (Stickle et al., 1989). Opportunistic infauna that commonly occur in offshore Alabama waters, such as the polychaetes *P. pinnata*, *Heteromastus filiformis*, and *Streblospio benedicti*, commonly inhabit hypoxic areas.

The relatively shallow-water benthic habitats of the inner shelf offshore Alabama are strongly influenced by abiotic factors such as temperature, wind and waves, river discharge (salinity and turbidity), currents and circulation, and tropical storms. The inherent variability of local benthic habitats causes the inner shelf infaunal community to be dynamic and unstable and to remain in an immature level of development, compared to a mature and stable community comprised of large, deep-dwelling, head-down deposit feeders. The Alabama inner shelf community probably remains in various stages of succession due to sporadic environmental disturbances, including seasonal and annual fluctuations in environmental parameters (Continental Shelf Associates, Inc. and Barry A. Vittor & Associates, Inc., 1989).

2.3.1.2 Epifauna and Demersal Ichthyofauna

Defenbaugh (1976) based the most detailed account of benthic macroinvertebrates of the northern Gulf region on extensive collections. The pro-delta sound assemblage includes the inshore and nearshore OCS from the Chandeleur Islands to the eastward boundary of the study area. Depths range from 4 to 20 m, and sediments are composed primarily of soft mud mixed with sand or shell hash; however, sediments are sandy east of Mobile Bay. Equivalent to Parker's (1960) open sound habitat, this assemblage is composed of such taxa as sea pansy *Renilla mulleri*; baby's ear gastropod *Sinum perspectivum*; bivalves *Chione clenchi* and *Noetia ponderosa*; brown shrimp *Penaeus aztecus*; shame-face crabs *Calappa sulcata* and *Hepatus epheliticus*; purse crabs *Persephona* spp.; and echinoderms *Hemipholis elongata* and *Mellita quinquiesperforata* (Table 2-2).

The intermediate shelf assemblage is a relatively broad area seaward of the pro-delta sound assemblage (Defenbaugh, 1976). Sediments are composed of muddy sand or sand in depths ranging from 20 to 60 m. This habitat contains the following taxa representative of the faunal assemblage: gastropods *Busycon*, *Fasciolaria*, *Murex*, and *Strombus*; bivalves *Argopecten, Pitar,*

Table 2-2. Epifaunal assemblages of the northern Gulf of Mexico which pertain to the Alabama study area (from Defenbaugh, 1976).

PRO-DELTA SOUND ASSEMBLAGE (4-20 m depth)

Cnidaria	Reptantia
Leptogorgia virgulata	*Calappa sulcata*
Renilla mulleri	*Callinectes similis*
Gastropoda	*Hepatus epheliticus*
Cantharus cancellarius	*Pagurus pollicaris*
Sinum perspectivum	*Persephona aquilonaris*
Bivalvia	*Persephona crinata*
Chione clenchi	*Portunus gibbesi*
Noetia ponderosa	Stomatopoda
Natantia	*Squilla empusa*
Penaeus aztecus	Echinodermata
Sicyonia dorsalis	*Hemipholis elongata*
Trachypeneus similis	*Luidia clathrata*
	Mellita quinquiesperforata
	Ophiolepis elegans

INTERMEDIATE SHELF ASSEMBLAGE (20-60 m depth)

Annelida	Reptantia
Diopatra cuprea	*Anasimus latus*
Gastropoda	*Calappa sulcata*
Busycon contrarium	*Callinectes similis*
Conus austini	*Hepatus epheliticus*
Distorsio clathrata	*Libinia emarginata*
Faciolaria l. hunteri	*Parthenope serrata*
Murex fulvescens	*Persephona crinata*
Pleurobranchaea hedgpethi	*Petrochirus diogenes*
Polystira albida	*Portunus gibbesi*
Strombus alatus	*Portunus spinicarpus*
Tonna galea	*Portunus spinimanus*
Bivalvia	Stomatopoda
Amusium papyraceus	*Squilla chydaea*
Argopecten gibbus	*Squilla empusa*
Chione clenchi	Echinodermata
Gouldia cerina	*Astropecten duplicatus*
Pitar cordata	*Clypeaster ravenelli*
Tellina nitens	*Echinaster* sp.
Tellina squamifera	*Encope michelini*
Natantia	*Luidia alternata*
Penaeus aztecus	*Luidia clathrata*
Penaeus setiferus	*Ophiolepis elegans*
Sicyonia brevirostris	*Stylocidaris affinis*
Sicyonia dorsalis	
Trachypeneus similis	

and *Tellina;* shrimps *Peneaus* and *Sicyonia*; crabs *Anasimus, Calappa, Libinia*, *Parthenope*, and *Portunus;* echinoids *Encope* and *Stylocidaris;* and sea stars *Astropecten* and *Luidia* (Table 2-2).

The MAME study (Harper, 1991) was the most recent major investigation of epifauna in the region of the sand resource areas. During this study, 310 species were collected by trawl, with decapods accounting for 48% of the species and 78% of the individuals collected. The numerical dominance of decapods was due to the large number of shrimps collected. Other than decapods, mollusks and echinoderms were the major contributors, comprising 30% and 18% of collected species, and 8% and 10% of individuals, respectively. Patterns of epifaunal similarity among stations in the MAME study were examined using cluster analysis. The inner stations of the De Soto Canyon and Mobile transects were located just within the southern edge of Sand Resource Areas 1 and 4, respectively, and were characterized by a common epifaunal assemblage that generally included shallow water and estuarine-related taxa. Numerical dominants common to both stations included the decapods *Sicyonia brevirostris* and *Trachypenaeus constrictus* and the squid *Loligo pealei*. Other numerical dominants were *Sicyonia dorsalis*, *Portunus gibbseii*, and the asteroid *Luidia clathrata*. Sediment at both MAME stations was characterized as sand (Harper, 1991).

Continental Shelf Associates, Inc. (1989) conducted a diver tow and photographic survey in OCS Pensacola Area Block 881 to characterize bottom habitats. The site of the survey was situated at the southern end of Sand Resource Area 2. Sandy sediments characterized the area, often consisting of shell hash and coarse sand. Frequently observed epifauna included burrowing anemones (cerianthids), portunid decapods, and echinoderms (*Astropecten duplicatus*, *Encope michelini*, and *L. clathrata*).

Darnell and Kleypas (1987) provided a comprehensive survey of demersal ichthyofauna of the eastern Gulf of Mexico shelf, from the Mississippi Delta to southwest Florida. Regional shelf waters supported about 347 species plus another 85 unresolved taxa from 80 families. The most speciose families included Bothidae (23 species), Serranidae (21 species), Sciaenidae (18 species), Triglidae (14 species), Ophidiidae (13 species), Carangidae (12 species), Sparidae (11 species), Gobiidae (11 species), Balistidae (10 species), Syngnathidae (10 species), and Scorpaenidae (9 species). Pinfish (*Lagodon rhomboides*) and longspine porgy (*Stenotomus caprinus*) were the most abundant species, together comprising about 19% of the catch. Total abundance was dominated by relatively few species; the top 13 species contributed over 50% of the entire catch.

In their survey, Darnell and Kleypas (1987) described several distinctive fish assemblages based on the co-occurrence of species in trawl samples. Within the study region, they identified the Mississippi Bight assemblage extending from the Mississippi Delta eastward to about Perdido Bay, Florida and out to the shelf break. Of six assemblages discussed by Darnell and Kleypas (1987), the Mississippi Bight fauna was by far the most diverse assemblage in the eastern Gulf of Mexico. Abundant species included striped anchovy (*Anchoa hepsetus*), rock seabass (*Centropristis philadelphica*), silver seatrout (*Cynoscion arenarius*), pinfish (*Lagodon rhomboides*), spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropognias undulatus*), and longspine porgy (*Stenotomus caprinus*).

The Geological Survey of Alabama (Hummell and Smith, 1995) summarized unpublished Southeastern Area Monitoring and Assessment Program (SEAMAP) trawl data collected during June 1985 and 1991 and October 1988 and 1993 from Sand Resource Area 4. Epifaunal taxa collected most consistently during these SEAMAP surveys included crab (*Callinectes similis*), shrimps (*Penaeus aztecus* and *P. setiferus*), squid (*Lolligunculua brevis*), and stomatopod (*Squilla empusa*). Demersal ichthyofauna collected most consistently during the SEAMAP surveys in Area 4 included bay anchovy (*Anchoa mitchilli*), silver seatrout, pinfish, Atlantic croaker, searobin (*Prionotus longispinous*), and lizardfish (*Synodus foetens*).

The Mississippi Bight area encompasses a zone of faunal transition for demersal fishes. This is presumably due to a sediment textural change from the mud of the Mississippi Delta to the more sandy, biogenic carbonate sediments of the West Florida Shelf. The affinity of certain demersal species for particular sediment types is often related to the types of prey items supported by those sediments (Rogers, 1977). Another factor thought to influence the distribution and abundance of fishes in this area is the reduced freshwater discharge (and sediment load) to shelf waters east of Mobile Bay (Barry A. Vittor & Associates, Inc., 1985).

Seasonally, the Mississippi Bight assemblage (Darnell and Kleypas, 1987) showed peak abundance (due to movement by a few species) in winter months on the middle and outer shelf. In general, this assemblage exhibited much less seasonality when compared with the northwestern Gulf fish assemblages. Mild winter temperatures and reduced riverine discharge east of the Mississippi River may contribute to the reduced seasonal movements by demersal species. Pattern analyses were performed by Comiskey et al. (1985) on various data sets from trawl surveys in the area of the present study, including 1974 to 1975 National Marine Fisheries Service (NMFS) fishery independent surveys and 1982 to 1983 SEAMAP surveys. These analyses indicated that the nearshore environment off Alabama was characterized by low numbers of taxa and individuals relative to areas nearer the Mississippi Delta. Inner shelf waters off Alabama apparently support a demersal community of spatially widespread taxa that migrate inshore seasonally, rather than distinct resident assemblages (Comiskey et al., 1985).

Barry A. Vittor & Associates, Inc. (1985) analyzed 1982 to 1983 SEAMAP trawl data using cluster analysis. This provided a fine-scale analysis of proximate environmental factors, such as hydrography and substratum type, that influence the distribution of demersal taxa (including motile epifauna) within the Darnell and Kleypas (1987) Mississippi Bight assemblage. Cluster analysis produced eight taxonomic groups explained primarily by sediment type and water depth (Table 2-3). Species diversity of the groupings was positively correlated with depth and salinity and negatively correlated with temperature, indicating that the deeper, more hydrographically stable habitats support a more diverse demersal community.

2.3.2 Pelagic Environment

Existing information on the pelagic environment is provided in this section to support discussions in Section 7.6 concerning potential impacts and schedules of best and worst times for offshore dredging with regards to transitory pelagic species. Ecological characteristics and seasonal distribution of zooplankton (including ichthyoplankton) and nekton (i.e., squids, fishes, sea turtles, and mammals) which occur in nearshore shelf waters of Alabama are described. Available literature for the Alabama coastal region was supplemented with data and information from surrounding waters when necessary to fill gaps and provide descriptions of organisms in the sand resource areas given their water depth and distance from shore.

2.3.2.1 Zooplankton

Zooplankton form essential links in the marine food web between primary producers (phytoplankton and bacteria) and larger marine species such as fishes, birds, and marine mammals. They are relatively weak swimmers that drift with water currents. Zooplankton transport organic matter through the water column by their vertical migration and production of organically rich fecal pellets which sink to the seafloor.

There have been numerous studies of zooplankton species composition and distribution in the eastern Gulf of Mexico and its estuaries, but few were directly applicable to the sand resource areas. Most studies in the region have been conducted in Mississippi coastal waters, Mississippi Sound, and Mobile Bay. Results of these studies provided general information on abundance and seasonality of various species groups.

Table 2-3. Eight taxonomic groups resulting from a synthesis of community analyses of trawl samples collected in the northeastern Gulf of Mexico study area during the 1982 and 1983 SEAMAP groundfish surveys (from Barry A. Vittor & Associates, Inc., 1985).	
Group 1. Shallow Water, Low Salinity Habitat	
Scientific Name	**Common Name**
Anchoa mitchilli	Bay anchovy
Anchoa nasuta	Longnose anchovy
Arius felis	Hardhead catfish
Chloroscombrus chrysurus	Atlantic bumper
Larimus fasciatus	Banded drum
Menticirrhus americaus	Southern kingfish
Polydactylus octonemus	Atlantic threadfin
Stellifer lanceolatus	Star drum
Trinectes maculatus	Hogchoker
Group 2. Widespread in Low Salinity Waters and in High Salinity Waters Overlying Muddy Sediments	
Scientific Name	**Common Name**
Anchoa hepsetus	Striped anchovy
Callinectes sapidus	Blue crab
Callinectes similis	Crab
Citharichthys spilopterus	Bay wiff
Cynoscion arenarius	Sand seatrout
Leiostomus xanthurus	Spot
Lolliguncula brevis	Squid
Penaeus aztecus	Brown shrimp
Penaeus setiferus	White shrimp
Peprilus burti	Gulf butterfish
Symphiurus plagiusa	Blackcheek tonguefish
Trichiurus lepturus	Atlantic cutlassfish
Group 3. Widespread in High Salinity Waters Overlying Muddy Sediments	
Scientific Name	**Common Name**
Brotula barbata	Bearded brotula
Calappa sulcata	Crab
Cynoscion nothus	Silver seatrout
Etropus crossotus	Fringed flounder
Lepophidium graellsi	Blackedge cusk-eel
Ophidion welshi	Crested cusk-eel
Porichthys plectrodon	Atlantic midshipman
Prionotus rubio	Blackfin searobin
Sicyonia dorsalis	Rock shrimp
Squilla LPIL	Mantis shrimp
Trachypenaeus LPIL	Hardback shrimp
Group 4. High Salinity Waters Overlying Muddy Sediments East of the Mississippi River	
Scientific Name	**Common Name**
Portunus gibbesii	Portunid crab
Prionotus tribulus	Bighead searobin
Saurida brasiliensis	Largescale lizardfish
Serranus atrobranchus	Blackear bass
Sphoeroides parvus	Least puffer
Urophycis cirratus	Gulf hake
Urophycis floridanus	Southern hake

Table 2-3. Continued.

Scientific Name	Common Name
Group 5. High Salinity Waters Overlying Muddy Sediments West of the Mississippi River Outfall	
Scientific Name	**Common Name**
Antennarius radiosus	Singlespot frogfish
Bollmania communis	Ragged goby
Gunterichthys longipenis	Gold brotula
Hoplunnis macrurus	Silver conger
Nezumia bairdi	Grenadier
Parapenaeus	Shrimp
Steindachneria argentea	Luminous hake
Group 6. High Salinity Waters Overlying Muddy and Sandy Sediments	
Scientific Name	**Common Name**
Centropristis philadelphicus	Rock sea bass
Diplectrum bivattatum	Dwarf sand perch
Etrumeus teres	Round herring
Halieutichthys aculeatus	Pancake batfish
Lepophidium jeannae	Mottled cusk-eel
Lutjanus campechanus	Red snapper
Ophidion grayi	Blotched cusk-eel
Ovalipes guadulpensis	Portunid crab
Penaeus duorarum	Pink shrimp
Portunus spinicarpus	Portunid crab
Prionotus roseus	Bluespotted searobin
Solenocera atlantidis	Shrimp
Stenotomus caprinus	Longspine porgy
Syacium gunteri	Shoal flounder
Synodus foetens	Inshore lizardfish
Group 7. Nearshore High Salinity Waters Overlying Sandy Sediments	
Scientific Name	**Common Name**
Centropristis ocyurus	Bank sea bass
Doryteuthis plei	Squid
Haemulon aurolineatum	Tomtate
Loligo pealei	Squid
Orthopristis chrysoptera	Pigfish
Prionotus carolinus	Northern searobin
Prionotus martis	Barred searobin
Prionotus scitulus	Leopard searobin
Raja eglanteria	Cleannose skate
Sicyonia brevirostris	Rock shrimp
Sphoeroides spengleri	Bandtail puffer
Group 8. Offshore High Salinity Waters Overlying Sandy Sediments	
Scientific Name	**Common Name**
Bellator militaris	Horned searobin
Lagodon rhomboides	Pinfish
Monacanthus hispidus	Planehead filefish
Neomerinthe hemingwayi	Spinycheek scorpionfish
Ophidion holbrooki	Bank cusk-eel
Prionotus salmonicolor	Blackwing searobin
Scorpaena calcarata	Smoothhead scorpionfish
Syacium papillosum	Dusky flounder
Synodus intermedius	Sand diver
Synodus poeyi	Offshore lizardfish
Trachinocephalus myops	Snakefish
Urophycis regius	Spotted hake

Zooplankton can be functionally divided into holoplankton and meroplankton. Holoplankton spend their entire lives in the water column, whereas meroplankton occur as plankton only during certain stages (generally larval stages) of their life cycle. Many important commercial and sport fish species have planktonic eggs and larvae. Almost without exception, the commercially important shellfish have planktonic larvae. Fish eggs and larvae are discussed separately in the ichthyoplankton section, which occurs after the sections on holoplankton and meroplankton.

Holoplankton

Major constituents of the holoplankton include protozoa, gelatinous zooplankton, copepods, mysids, and chaetognaths. Other groups include amphipods, euphausiids, heteropods, ostracods, polychaetes, and pteropods.

Among protozoans, ciliates have received the most attention. Approximately 116 ciliate genera and about 215 ciliate species are known in the Gulf of Mexico (Borror, 1962). Tintinnids are a group of common, marine, ciliated protozoans which live within a tube-like covering. Balech (1967) reported 55 tintinnid species from the NEGOM.

Gelatinous zooplankton constitute an important group in the northern Gulf of Mexico. Phillips et al. (1969) studied macroplanktonic jellyfishes in the northern Gulf of Mexico and found them to be essential links via food webs and symbiotic relationships to the benthos, nekton, and other zooplankters. Phillips et al. (1969) and Burke (1975, 1976) listed 1 chondrophore, 2 ctenophores, 12 hydromedusae, 7 scyphomedusae, and 5 siphonophores from nearshore waters off Mississippi. Hydromedusae (i.e., *Liriope tetraphylla*, *Bougainvillia carolinensis*, *Nemopsis bachei*) were most abundant. Scyphomedusae were numerically dominated by the sea nettle *Chrysaora quinquecirrha* and the cabbagehead jellyfish *Stomolophus meleagris*. The cabbagehead jellyfish, along with the ctenophore *Mnemiopsis mccradyi,* can be so plentiful (up to 10/m^2 or more) that they interfere with commercial shrimp and fish trawling operations. In the Mississippi Sound region, Christmas (1973) found that *M. mccradyi* was always the dominant zooplankton species in terms of biomass. The ctenophore *M. mccradyi* is a major predator of microzooplankton, including copepods and bivalve larvae (Reeve and Walter, 1978).

Another small, but important, group of filter-feeding gelatinous zooplankton includes the larvaceans. They are one of the few zooplankton groups that can feed on bacteria-sized particles. The only larvacean that is common in northern Gulf of Mexico inshore waters is *Oikopleura dioica*. Off Florida, Hopkins (1966) reported that *O. dioica* formed about 8% of the total zooplankton densities in St. Andrew Bay. Edmiston (1979) found that this species constituted about 3% of the zooplankton densities off Apalachicola Bay.

Copepods are the numerically dominant group of net-collected zooplankton. These small crustaceans are mainly herbivorous and opportunistic, forming an important link in the food web between phytoplankton and micronekton. Copepods feed on whatever species of phytoplankton is most abundant within a size range of about 5 to 75 μm (Turner, 1984a,b,c,d, 1986). McIlwain (1968) reported 15 copepod taxa from Mississippi Sound. Numerically dominant species in his samples were *Acartia tonsa*, *Labidocera aestiva*, *Oithona brevicornis*, and *Paracalanus parvus*. Table 2-4 shows the monthly occurrence of all copepod taxa collected by McIlwain (1968). Zooplankton collections from nearshore waters offshore Mississippi and Alabama (<25 m water depths) included the copepod genera *Acartia*, *Centropages*, *Eucalanus, Oithona*, and *Paracalanus* (Alexander et al., 1977).

Mysids are shrimp-like crustaceans which are categorized (depending on their size and behavior) as either zooplankton, micronekton, or epibenthos. They are important food for fishes. Seventeen species of mysids are known from nearshore shelf waters in the northern Gulf of Mexico (Stuck et al., 1979). In the vicinity of Dauphin Island, Alabama, five mysid species are common, with three species (*Mysidopsis almyra*, *Bowmaniella brasiliensis*, and *B. floridana,*) accounting for about 85% of the mysids collected (Modlin, 1982).

Chaetognaths are a small, but significant, group of zooplankton. They form an important trophic link between copepods and larger predators, including commercially important fishes (McLelland, 1989). Twenty-four species are known from the Gulf of Mexico, but only a few are common inshore (McLelland, 1989). In nearshore waters of the NEGOM, four species of *Sagitta* predominate: *S. friderici*, *S. helenae*, *S. hispida,* and *S. tenuis*, (McLelland, 1984). The onshore/offshore distribution of these species is affected by tolerance to salinity changes (McLelland, 1984).

Table 2-4. Monthly occurrence of copepods collected in Mississippi Sound (adapted from McIlwain, 1968).

Species	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Acartia tonsa	•	•		•	•	•	•	•	•	•	•	
Centropages furcatus						•	•	•	•	•	•	•
Centropages hamatus											•	•
Corycaeus sp.						•	•	•	•			
Eucalanus pileatus		•				•	•	•	•		•	
Euterpina acutifrons		•				•	•	•	•		•	•
Labidocera aestiva				•	•	•	•	•	•	•	•	
Labidocera sp.	•	•					•		•	•	•	
Oithona brevicornis				•	•	•	•	•	•	•	•	•
Oithona sp.		•					•					
Oncaea venusta						•	•	•				
Paracalanus parvus				•	•	•	•		•	•	•	
Sapphirina nigromaculata		•						•				
Temora longicornis						•	•	•	•	•	•	
Temora stylifera								•				

Meroplankton

Meroplankton includes organisms occurring as plankton only during certain stages (generally larval stages) of their life cycle. Major meroplanktonic groups are planktonic larvae of benthic invertebrates (e.g., polychaetes, gastropods, bivalves, decapods, echinoderms, and cephalochordates) and fishes. Fish eggs and larvae are discussed separately in the following ichthyoplankton section.

Planktonic larvae of benthic invertebrates are a significant component of the coastal zooplankton. The occurrence of crab larvae in the northern Gulf of Mexico was studied by Truesdale and Andryszak (1983). They found larvae of portunid (swimming) crabs at every station, with *Callinectes* spp. (mostly *C. sapidus* [blue crab] and *C. similis*) and *Portunus* spp. larvae being most abundant. Early zoeal stages of *Callinectes* spp. were confined mostly to inshore waters, whereas later stages occurred mostly offshore. Other numerically important crab larvae were *Uca* spp. (fiddler crabs) and *Pagurus pollicaris* and *Clibanarius vittatus* (hermit crabs). Stuck and Perry (1981a) described the seasonal distribution of blue crab megalops larvae in Mississippi coastal waters. They collected megalopae in all months of the year, but peak settlement occurred in fall. More recently, Perry et al. (1995) and Rabalais et al. (1995) investigated the seasonal recruitment patterns of blue crab megalopae near major passes in the north-central Gulf of Mexico including Mobile Bay and Mississippi Sound. Settlement of blue crab megalops larvae was estimated using collecting traps that provided continuous sampling over time. Over a 2-yr monitoring period, the settlement of megalopae occurred primarily from August to November (with intra-month peaks). Despite their relative proximity, there was a 5-day lag in settlement between Mississippi Sound and Mobile Bay (Rabalais et al., 1995).

Although not strictly planktonic, the occurrence of post-larval (recently settled) penaeid shrimps provides a clue to the seasonality of the late-stage planktonic larvae. Christmas et al. (1966) described the seasonal distribution of post-larval penaeid shrimps in Mississippi Sound using towed nets. Brown shrimp post-larvae appeared as early as February and continued through August. White shrimp post-larvae occurred in April and persisted through September. Pink shrimp post-larvae first appear in June and were collected until October.

Many meroplankters that use estuarine habitats as juveniles originate offshore in adult spawning areas where eggs and larvae are released in the water. Although exact mechanisms are not well understood, the transport of meroplankters to their juvenile habitat depends upon local and regional circulation processes including coastal currents, wind regime, and tidal influence as well as the behavior of the organism (Shaw et al., 1988). Parcels of coastal water can be displaced for hundreds of kilometers, thus larvae do not necessarily enter estuaries nearest to the offshore spawning sites (Shaw et al., 1988).

The ingress (inshore migration) of penaeid shrimp larvae was modeled by Rogers et al. (1993) for Louisiana coastal waters. This process was thought to involve behavioral responses to environmental cues that allow the post-larval shrimp to take advantage of prevailing physical forces. These researchers suggested that the ingress of larval brown shrimp from offshore waters to inshore marsh habitats was facilitated by environmental cues provided by the passage of cold fronts. The post-cold front southerly winds generated northward flowing currents which transported the brown shrimp post-larvae shoreward (Rogers et al., 1993).

Ichthyoplankton

Most fishes inhabiting the Gulf of Mexico, whether pelagic or benthic as adults, have pelagic larval stages. For various lengths of time (10 to 100 days, depending on the species), these pelagic fish eggs and larvae become part of the planktonic community known as ichthyoplankton (Leis, 1991). Variability in survival and transport of pelagic larval stages is thought to be an important determinant of future year class strength in adult populations of fishes and invertebrates (Underwood and Fairweather, 1989). For this reason, larval fishes and the physical and biological factors that influence their abundance and distribution have received increasing attention from marine ecologists. In general, the distribution of fish larvae depends upon 1) spawning behavior of adults; 2) hydrographic structure at a variety of scales; 3) duration of the pelagic period; 4) behavior of larvae; and 5) larval mortality and growth (Leis, 1991).

In this section, major ichthyoplankton studies relevant to the project area are reviewed and discussed. There was no information on ichthyoplankton available for the immediate vicinity of the five sand resource areas. Therefore, available information was used from studies conducted in nearby areas such as lower Mobile Bay, Mississippi Sound, and coastal Mississippi.

Ichthyoplankton assemblages in nearshore shelf waters of the region are composed of species that also are common as adults (Ditty, 1986; Ditty et al., 1988). The temporal occurrence of these taxa in ichthyoplankton samples reflects the spawning times of adults. In the northern Gulf of Mexico, spawning activity can be broadly classified as cold water and warm water periods which parallel the seasons (Barry A. Vittor & Associates, Inc. 1985). Because generally expected seasonal patterns of fish egg and larval occurrence can be inferred from knowledge of the known adult spawning times, this information is presented to augment information on the temporal patterns of ichthyoplankton occurrence. Table 2-5 gives the spawning times for economically important species from the region.

Ditty et al. (1988) summarized information from over 80 ichthyoplankton studies from the northern Gulf of Mexico (north of 26°N) and reported 200 coastal and oceanic fishes from 61 families. Many taxa were only collected over waters within certain depth ranges. Species found exclusively in water depths shallower than 25 m were mostly inshore demersal species such as Atlantic bumper (*Chloroscombrus chrysurus*), spotted seatrout (*Cynoscion nebulosus*), pigfish (*Orthopristis chrysoptera*), and black drum (*Pogonias cromis*). At depths <100 m, several clupeids (*Brevoortia patronus*, *Opisthonema oglinum*, and *Sardinella aurita*), several serranids (*Centropristis striata*, *Diplectrum formosum*, and *Serraniculus pumilio*), Atlantic croaker (*Micropogonias undulatus*), and spot (*Leiostomus xanthurus*) were most common in collections.

Local ichthyoplankton surveys from near Mobile Bay (Marley, 1983; Shipp, 1982, 1984, 1987) and offshore of Mississippi (Stuck and Perry, 1981b) revealed less diverse assemblages. Stuck and Perry (1981b) collected 95 taxa in 43 families during a year-long survey. Monthly occurrences of the most important taxa collected in their survey are given in Table 2-6. Three families numerically dominated the catches: jacks (Carangidae), anchovies (Engraulidae) and drums (Sciaenidae). Atlantic bumper was the most abundant taxon collected, representing 38.8% of the catches. Most larval fishes were collected during a 7-month period from April to October; catches decreased considerably during colder months (November to March).

Species such as Atlantic croaker, spot, and Gulf menhaden (*Brevoortia patronus*) migrate to the outer shelf during winter months to spawn. Consequently, larvae of these species often are numerically dominant during winter months (Shipp, 1987). Larvae of speciose families such as engraulids (*Anchoa* spp.), searobins (*Prionotus* spp.), tonguefishes (*Symphurus* spp.), and pufferfishes (*Sphoeroides* spp.) were collected during all months (Shipp, 1984, 1987).

Larval fishes are highly dependent on small zooplankton until they can feed on larger prey. In the northern Gulf of Mexico, the diets of Atlantic croaker, Gulf menhaden, and spot consist mainly of copepods and copepod nauplii, larval bivalves, pteropods, and the dinoflagellate *Prorocentrum* sp. (Govoni et al., 1989).

Although Mobile Bay has not been studied specifically, its discharge plume could serve as an important aggregation site for larval fishes. A series of investigations has shown that ichthyoplankton aggregate at the frontal zone of the Mississippi River discharge plume (Govoni et al., 1989; Grimes and Finucane, 1991; Govoni and Grimes, 1992). Grimes and Finucane (1991) sampled larval fishes, chlorophyll *a*, and zooplankton along transects traversing the discharge plume. Total ichthyoplankton catch per tow, individual surface chlorophyll *a* values, and zooplankton volumes were all significantly greater in frontal waters than adjacent shelf or plume waters. Hydrodynamic convergence and the continually reforming turbidity fronts associated with the discharge plume probably accounted for the concentration of larval fishes at the front. These investigators hypothesized that frontal waters provide feeding and growth opportunities for larvae. Bothids (lefteye flounders), carangids, cynoglossids (tonguefishes) engraulids, exocoetids (flying fishes and halfbeaks), gobiids (gobies), sciaenids, scombrids (mackerels and tunas), synodontids (lizardfishes), and tetraodontids (pufferfishes) were the 10 most frequently caught taxa in the plume/shelf samples off the Mississippi River Delta (Grimes and Finucane, 1991).

Table 2-5. Spawning times of economically important fishes (F) and invertebrates (I) in the northern Gulf of Mexico (adapted from Barry A. Vittor & Associates, Inc., 1985).												
Species	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Cold Water Spawners												
Archosargus probatocephalus(F)												
Brevoortia patronus (F)												
Leiostomus xanthurus (F)												
Micropogonias undulatus (F)												
Mugil cephalus (F)												
Paralichthys albigutta (F)												
P. lethostigma (F)												
Peprilus burti (F)												
Pogonias cromis (F)												
Pomatomus saltatrix (F)												
Penaeus aztecus (I)												
Warm Water Spawners												
Arius felis (F)												
Caranx hippos (F)												
Cynoscion arenarius (F)												
C. nothus (F)												
Lutjanus campechanus (F)												
L. synagris (F)												
Peprilus alepidotus (F)												
Rachycentron canadum (F)												
Sciaenops ocellatus (F)												
Scomberomorus maculatus (F)												
Tarpon atlanticus (F)												
Penaeus duorarum (I)												
P. setiferus (I)												
Year Round Spawners												
Anchoa mitchilli (F)												
Caranx crysos (F)												

Table 2-6. Occurrence ( ) and peak seasonal occurrence ( ) of larval fishes in coastal waters of Mississippi (Adapted from: Stuck and Perry, 1981b).

Family	Genus/Species	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
Clupeidae	*Brevoortia* spp.												
	B. patronus			•	•					•	•	•	
Engraulidae	*Anchoa* spp.	•	•								•	•	•
	A. hepsetus	•	•	•	•	•	•	•	•	•	•	•	•
Ophidiidae	*Brotula barbata*	•										•	•
Syngnathidae	*Hippocampus erectus*				•	•			•		•		
	Syngnathus floridae				•	•	•		•	•			
	S. louisianae				•	•	•	•	•	•	•	•	•
Serranidae	*Centropristis* spp.	•	•	•	•	•		•		•	•	•	•
	C. striata	•	•	•		•				•	•	•	
	Diplectrum spp.	•	•	•	•					•	•	•	•
	D. formosum	•	•	•			•	•			•	•	
Carangidae	*Caranx* sp.	•	•	•	•	•	•	•	•	•	•	•	•
	C. crysos			•	•	•				•	•	•	
	Chloroscombrus chrysurus				•	•					•		
	Decapterus punctatus			•							•	•	
	Oligoplites saurus				•	•				•	•	•	
	Selar crumenopthalmus				•	•	•	•	•	•	•		
	Selene spp.					•	•				•	•	
	Trachinotus spp.				•	•	•	•	•	•			
Sparidae	*Archosargus probatocephalus*				•	•							
	Lagodon rhomboides	•	•	•	•							•	•
Sciaenidae	*Bairdiella chrysoura*			•						•	•		
	Cynoscion arenarius		•			•	•			•	•		
	C. nebulosus		•	•						•	•		
	C. nothus					•	•	•	•			•	
	Larimus fasciatus				•	•	•	•	•		•	•	
	Leiostomus xanthurus		•	•	•						•	•	
	Menticirrhus spp.		•	•	•	•	•	•	•	•	•	•	•
	Micropogonias undulatus		•	•	•					•			
	Sciaenops ocellatus								•			•	
	Stellifer lanceolatus				•	•	•	•	•	•	•		
Mugilidae	*Mugil cephalus*	•	•	•	•	•	•	•	•	•	•	•	•
Scombridae	*Scomberomorus maculatus*				•	•	•	•	•	•			

Table 2-6. Continued.

Stromateidae	*Peprilus alepidotus*				•	•	•	•	•	•	•	•	
	P. burti	•	•	•	•	•	•				•	•	•
Triglidae	*Prionotus* spp.				•	•	•	•		•	•	•	
Bothidae	*Citharichthys/Etropus* spp.				•	•	•	•	•	•	•	•	•
	Citharichthys spilopterus	•	•	•		•	•				•	•	
	Paralichthys spp.			•	•				•				
Cynoglossidae	*Symphurus* spp.				•	•				•	•	•	•
Balistidae	*Monacanthus hispidus*					•	•	•	•	•	•		•
Tetraodontidae	*Sphoeroides* spp.				•	•	•	•	•				
	S. parvus					•	•	•		•		•	

2.3.2.2 Squids

Squids (cephalopods) display patchy distributions and periodic vertical and horizontal migrations. Water quality, currents, and temperature principally control the occurrence of squids, while food and population density affect movements within suitable water masses.

Squids most likely to occur in or near the project area include *Doryteuthis plei*, *Loligo pealei*, and *Loliguncula brevis*. *Loliguncula brevis* is common nearshore, frequenting salinities as low as 17 ppt. *Doryteuthis plei* and *L. pealei* usually live in the more saline shelf waters (Lipka, 1975). The most recent commercial catch statistics from the NMFS (U.S. Department of Commerce, NMFS, 1998) indicate that some squids are caught and sold in the eastern Gulf, particularly the northernmost locations. *Loligo* and *Loliguncula* make up the bulk of this catch, although neither the fishermen nor the markets separate the catch by species. This catch is both temporally and geographically variable, but is consistently of minimal commercial importance, contributing much less than 1% of the total commercial catch of all species from any reporting grid. The bulk of the squid catch appears to be bycatch from the commercial shrimping fleet.

2.3.2.3 Fishes

Pelagic fishes occur throughout the water column from the beach to the open ocean. Water column structure (temperature, salinity, turbidity) partitions this vast habitat. On a broad scale, pelagic fishes recognize different water masses based upon physical and biological characteristics. The basic subdivision of pelagic fishes is oceanic pelagic and coastal pelagic. Primarily coastal pelagic species are found in the vicinity of the sand resource areas.

Major coastal pelagic families occurring in the region are Carcharhinidae (requiem sharks), Elopidae (ladyfish), Engraulidae (anchovies), Clupeidae (herrings), Scombridae (mackerels and tunas), Carangidae (jacks and scads), Mugilidae (mullets), Pomatomidae (bluefish), and Rachycentridae (cobia). Coastal pelagic species traverse shelf waters of the region throughout the year. Some species form large schools (e.g., Spanish mackerel, *Scomberomorus maculatus*), while others travel singly or in small groups (e.g., cobia, *Rachycentron canadum*). The distribution of most species depends upon water column structure, which varies spatially and seasonally. Some coastal pelagic species show an affinity for vertical structure and are often observed around natural or artificial structures (e.g., dredges or oil and gas platforms), where they are best classified as transients rather than true residents. This is particularly true for Spanish sardine (*Sardinella aurita*), round scad (*Decapterus punctatus*), blue runner (*Caranx crysos*), king mackerel (*Scomberomorus cavalla*), and cobia (Klima and Wickham, 1971; Chandler et al., 1985).

Coastal pelagic fishes can be divided into two ecological groups. The first group includes large predatory species such as king and Spanish mackerels, bluefish (*Pomatomus saxatilis*), cobia, jacks (*Caranx* spp.), and little tunny (*Euthynnus alletteratus*). These species typically form schools, undergo migrations, grow rapidly, mature early, and exhibit high fecundity. Each of these species is important to some extent to regional fisheries. The second group exhibits similar life history characteristics, but the species are smaller in body size and planktivorous. This group is composed of anchovies (*Anchoa* spp.), Gulf menhaden (*Brevoortia patronus*), round scad, Spanish sardine, striped mullet (*Mugil cephalus*), and thread herring (*Opisthonema oglinum*). Species in the second group are preyed upon by the larger species in the first group; thus, the two are ecologically important in energy transfer in the nearshore environment (Saloman and Naughton, 1983a,b, 1984a,b). The food habits of five predatory species (bluefish, cobia, crevalle jack [*Caranx hippos*], and king and Spanish mackerels) in the northern Gulf of Mexico are given in Table 2-7.

With the exception of king mackerel, migratory routes and schedules of the large-bodied, predatory coastal pelagic species are not well known or documented. King mackerel occurring in the shelf waters of the region actually may come from two distinct populations (Johnson et al., 1994). The eastern population migrates from near the Mississippi Delta eastward, then southward around the Florida peninsula, wintering off southeastern Florida (Sutter et al., 1991). The western population travels to waters off the Yucatan Peninsula during winter. In summer, both populations migrate to the northern Gulf of Mexico, where they intermix to an unknown extent (Johnson et al., 1994). Spanish mackerel, cobia, bluefish, crevalle jack, and coastal sharks (*Carcharhinus* spp.) are migratory, but their routes have not been studied. Spanish mackerel, bluefish, and crevalle jack generally migrate westward along the shelf in warm months and back eastward towards Florida during cold months (Barry A. Vittor & Associates, 1985).

Coastal pelagic fishes are important to both commercial and recreational fisheries of the region. Fisheries landings provide the best available source of temporal patterns in occurrence of coastal pelagic species in the region (Table 2-8). Commercial purse seine fisheries landed 392 metric tons of coastal pelagic species offshore Alabama in 1997 (U.S. Department of Commerce, NMFS, 1998). Some species are targeted by the purse seine fishery while others are captured incidentally (Da Silva and Condrey, 1998). The Gulf menhaden fishery perennially produces the highest fishery landings in the continental U.S. (U.S. Department of Commerce, 1991). Menhaden form large, surface feeding schools in waters near the Mississippi Delta and eastward to Florida from April through September. Fishermen take advantage of this schooling behavior, capturing millions of pounds each year with large purse nets. Other coastal pelagic species contributing high commercial landings in the region include striped mullet and Spanish mackerel (Table 2-8).

2.3.2.4 Sea Turtles

Five species of sea turtles may occur offshore Alabama (Table 2-9). All are protected under the Endangered Species Act of 1973. The loggerhead sea turtle (*Caretta caretta*) is a threatened species. The hawksbill (*Eretmochelys imbricata*), Kemp's ridley (*Lepidochelys kempii*), and leatherback (*Dermochelys coriacea*) sea turtles are endangered species. The Atlantic green sea turtle (*Chelonia mydas*) is threatened, except for the Florida breeding population, which is endangered.

Loggerheads are expected to be the most common turtle in the project area, as they are the most abundant turtle on the northern Gulf shelf (Lohoefener et al., 1990; Mullin and Hoggard, 1998). Lohoefener et al. (1990) estimated that 92% of the turtles they observed during aerial surveys of the northern Gulf were loggerheads. Leatherbacks are abundant in the northern Gulf, but primarily in deep waters of the continental slope and beyond (Hansen et al., 1996; Mullin and Hoggard, 1998);

Table 2-7. Food habits of coastal pelagic fishes collected from the northern Gulf of Mexico.			
COMMON NAME	Scientific Name	Primary Stomach Contents (based on percent occurrence)	Area and Source
Bluefish	*Pomatomus saltatrix*	Fishes (herrings, jacks, drums, and seatrout)	Northwest Florida (Saloman and Naughton, 1984b)
Cobia	*Rachycentron canadum*	Crustaceans (swimming crabs and mantis shrimps)	Louisiana, Mississippi, Alabama, and Florida (Meyer and Franks, 1996)
Crevalle jack	*Caranx hippos*	Fishes (herrings and jacks)	Northwest Florida (Saloman and Naughton, 1984a)
King mackerel	*Scomberomorus cavalla*	Fishes (herrings, jacks, and unidentified)	Northwest Florida (Saloman and Naughton, 1983a)
Spanish mackerel	*Scomberomorus maculatus*	Fishes (herrings, jacks, and unidentified)	Northwest Florida (Saloman and Naughton, 1983b)

Table 2-8. Monthly commercial landings (lbs) of coastal pelagic fishes for Alabama averaged over the years 1992 to 1996 (U.S. Department of Commerce, National Marine Fisheries Service, 1998).

Species	Month												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Menhaden	144,828	74,133	160,974	656,885	1,015,611	640,227	1,086,096	663,861	881,567	247,331	50,219	126,992	5,748,724
Striped mullet	186,366	143,129	202,929	129,637	122,614	134,230	167,661	211,244	248,348	346,568	890,641	207,599	2,990,966
Other mullets	0	0	0	0	0	0	0	0	0	113,875	557,210	37,315	708,400
Spanish mackerel	0	0	0	523,550	21,232	1,016	7,560	34,089	12,324	5,989	0	0	605,760
Sharks (Unclassified)	0	15,146	4,857	15,008	0	0	0	0	0	67,946	0	0	102,957
Blue runner	0	0	0	18,777	0	0	0	0	0	0	0	0	18,777
Bluefish	0	0	0	2,079	0	2,507	1,160	1,484	6,578	226	0	0	14,034
Cobia	0	0	0	613	1,486	1,241	831	0	313	0	0	0	4,484

Table 2-9. Sea turtle species potentially occurring in coastal Alabama waters.				
Common Name	Scientific Name	Habitat Associations	Diet (adults)	Nesting Season [a] (Fla. Panhandle area)
Loggerhead sea turtle	*Caretta caretta*	Coastal, shelf, and slope waters	Benthic fauna (generalist)	May 1 - Nov 30
Green sea turtle	*Chelonia mydas*	Shallow coastal waters, seagrass beds	Seagrasses, algae, associated organisms	May 1 - Oct 31[b]
Leatherback sea turtle	*Dermochelys coriacea*	Coastal, shelf, and slope waters (most abundant on slope)	Cnidarians (e.g., jellyfishes)	May 1 - Sept 30[b]
Kemp's ridley sea turtle	*Lepidochelys kempii*	Shallow coastal waters, seagrass beds	Crabs, shrimps, etc.	(no nesting in area)
Hawksbill sea turtle	*Eretmochelys imbricata*	Coral reefs, hard bottom areas	Sponges	(no nesting in area)

[a] Sea turtle nesting seasons for the Florida Panhandle area as stated by the Minerals Management Service (1997).

[b] Green sea turtles are listed as nesting on Alabama beaches, but leatherbacks are not (Alabama Game and Fish Division, 1997). However, occasional nests and false crawls for both species have been observed nearby in the Florida Panhandle area (summarized by Minerals Management Service, 1997).

however, they also occur on the shelf in smaller numbers. Green, hawksbill, and Kemp's ridley turtles are typically inshore species that may occur in the project area, but little is known of their abundance.

There is a significant nesting subpopulation of loggerhead turtles along the Florida Panhandle, and some loggerhead nesting on Alabama beaches. Therefore, increased loggerhead densities may be expected during nesting season, which in the Panhandle region extends from 1 May through 30 November (Minerals Management Service, 1997). Although green turtles may nest on Alabama beaches (Alabama Game and Fish Division, 1997), the Minerals Management Service (1997) indicates that green turtle nesting in the northern Gulf is "isolated and infrequent" during the season lasting from 1 May through 31 October. Leatherbacks occasionally nest on Florida Panhandle beaches from 1 May through 30 September (Minerals Management Service, 1997) but are not listed as nesting in Alabama by the Alabama Game and Fish Division (1997). Hawksbill and Kemp's ridley turtles do not nest anywhere near the project area.

In addition to the occurrence of sea turtle adults, juveniles, and hatchlings in the water column, some adults may partially bury themselves in bottom sediments to avoid cold spells during winter. This phenomenon is known as "brumation" (essentially another term for hibernation) (Carr et al., 1981; Byles and Dodd, 1989). Little is known of the frequency of this behavior or the likelihood of turtles brumating in bottom sediments of the project area during winter. Lohoefener et al. (1990) reported that some loggerheads observed in the northern Gulf during February and March had mud lines on their carapaces, possibly indicating that the turtles had buried themselves in bottom sediments. In south Florida, Byles and Dodd (1989) noted that a female loggerhead brumated for periods up to 5 days when water temperatures fell below 18ºC. Green sea turtles also may brumate during cold weather (Ehrhart, 1977).

Loggerhead Sea Turtle

The loggerhead sea turtle is found in estuarine, coastal, and shelf waters from South America to Newfoundland. Adults of this predominantly subtropical species occur widely in coastal and shelf waters of the northern Gulf of Mexico, where they are the most abundant turtles seen during aerial surveys (Lohoefener et al., 1990; Mullin and Hoggard, 1998). Juveniles are pelagic, inhabiting wrack lines and *Sargassum* rafts and drifting in current gyres for several years. It is believed that subadults move into nearshore and estuarine areas.

Loggerhead nesting in U.S. waters occurs from New Jersey to Texas (Frazier, 1995), and at least four nesting subpopulations have been identified (Byles et al., 1996). The major U.S. nesting area is in southeastern Florida, which is second only to Oman in worldwide importance (Dodd, 1988; National Research Council, 1990; NMFS, 1990). Much smaller but important regular nesting aggregations occur in South Carolina, Georgia, and North Carolina. In the NEGOM, there is a Florida Panhandle nesting subpopulation located in the vicinity of Eglin Air Force Base and the Panama City area (Byles et al., 1996). Nesting has been reported on Gulf Shores and Dauphin Island, Alabama (Fuller et al., 1987). The Florida Panhandle nesting season extends from 1 May through 30 November (Minerals Management Service, 1997). Incubation lasts about 60 to 95 days. Hatchlings swim offshore and begin a pelagic existence within *Sargassum* rafts.

Loggerhead adults are generalist carnivores feeding primarily on nearshore benthic mollusks and crustaceans (Dodd, 1988). Pelagic stages feed on coelenterates and cephalopods.

Atlantic Green Sea Turtle

The Atlantic green sea turtle has a circumglobal distribution in tropical and subtropical waters. In the U.S., it occurs in Caribbean waters around the U.S. Virgin Islands and Puerto Rico, and along the mainland coast from Texas to Massachusetts. Green turtles are typically found in shallow coastal waters, particularly in association with seagrass beds.

The primary nesting sites in U.S. Atlantic waters are high-energy beaches along the east coast of Florida, with additional sites in the U.S. Virgin Islands and Puerto Rico (NMFS and U.S. Fish and Wildlife Service [USFWS], 1991). The Minerals Management Service (1997) indicates that reports of green turtle nesting in the northern Gulf are "isolated and infrequent," including beaches of the Florida Panhandle and unconfirmed reports of nesting in Alabama. The Alabama Game and Fish Division (1997) lists green turtles as nesting on Alabama beaches. Hatchlings swim out to sea and enter a pelagic stage in *Sargassum* mats associated with convergence zones.

Adult green turtles commonly feed on seagrasses, algae, and associated organisms, using reefs and rocky outcrops near seagrass beds for resting areas. Important feeding grounds in Florida, including Indian River Lagoon, the Florida Keys, Florida Bay, Homosassa, Crystal River, and Cedar Key, are all well to the south of the project area.

Leatherback Sea Turtle

The leatherback sea turtle is a circumglobal species, currently divided into two subspecies (Thompson and Huang, 1993). The subspecies of interest here is *Dermochelys coriacea coriacea* which inhabits waters of the western Atlantic Ocean from Newfoundland to northern Argentina. The leatherback is the largest living turtle (Eckert, 1995), and with its unique deep-diving abilities (Eckert et al., 1986) and wide-ranging migrations, is considered the most pelagic of the sea turtles (Marquez, 1990). It is the most abundant turtle on the continental slope of the northern Gulf (Hansen et al., 1996; Mullin and Hoggard, 1998). However, leatherbacks also can be present in shelf waters (Lohoefener et al., 1990; Mullin and Hoggard, 1998).

Leatherbacks nest on coarse-grained, high-energy beaches (i.e., beaches exposed to strong wave action) in tropical latitudes (Eckert, 1995). Florida is the only location in the continental U.S. where significant leatherback nesting occurs. Nesting on the Atlantic coast of Florida may sometimes approach that reported in the Caribbean, but nest density is considerably lower. Some nesting along the Florida Panhandle has been reported between 1 May and 30 September (Minerals Management Service, 1997), but leatherbacks are not listed as nesting on Alabama beaches (Alabama Game and Fish Division, 1997). Incubation lasts about 60 to 75 days. Very little is known of the pelagic distribution of hatchling and/or juvenile leatherback turtles.

Adult leatherbacks feed primarily on cnidarians (medusae, siphonophores) and tunicates (salps, pyrosomas) (Eckert, 1995). The turtles are sometimes observed in association with jellyfishes, but actual feeding behavior only occasionally has been documented. Foraging has been observed at the surface, but also is likely to occur at depth (Eckert, 1995).

Kemp's Ridley Sea Turtle

The Kemp's ridley sea turtle is the smallest and most endangered of the sea turtles. Its distribution extends from the Gulf of Mexico to New England, and occasionally as far north as Nova Scotia. Adult turtles are usually found in the Gulf of Mexico, primarily in shallow coastal waters less than 50 m deep (Byles, 1988). Juveniles may move northward along the U.S. Atlantic coast in spring with the Gulf Stream to feed in productive, coastal waters between Georgia and New England (NMFS and USFWS, 1992); these migrants then move southward with the onset of cooler temperatures in late fall and winter. In the Gulf of Mexico, juvenile Kemp's ridleys occupy nearshore waters (Rudloe et al., 1991; Shaver, 1991; Renaud, 1993), but they may move to deeper waters as temperatures cool during winter (Henwood and Ogren, 1987).

Nesting of Kemp's ridleys occurs almost entirely at Rancho Nuevo beach, Tamaulipas, Mexico, where 95% of the nests are laid along 60 km of beach (NMFS and USFWS, 1992; Weber, 1995). More than half of the adult females nest every year between April and mid-August, while the remainder may or may not skip certain years (National Research Council, 1990). In the U.S., nesting occurs infrequently on Padre and Mustang Islands in south Texas from May to August. No Kemp's ridley nesting occurs near the project area.

After emerging, Kemp's ridley hatchlings swim offshore to inhabit *Sargassum* mats and drift lines associated with convergences, eddies, and rings, where they feed at the surface. Adult Kemp's ridleys are carnivorous benthic feeders, preferring crabs, but also occasionally eating mollusks, shrimp, dead fishes, and vegetation (Mortimer, 1982; Lutcavage and Musick, 1985; Shaver, 1991; Burke et al., 1993; Werner and Landry, 1994). When adult ridleys are not migrating to or from their nesting beach, they inhabit crab-rich waters, such as those close to the Mississippi River Delta (Pritchard, 1989; National Research Council, 1990). The distribution of Kemp's ridleys also is associated with seagrass beds, which support a rich crustacean fauna (Lutcavage and Musick, 1985).

Hawksbill Sea Turtle

Hawksbill sea turtles occur in tropical and subtropical seas of the Atlantic, Pacific, and Indian Oceans. In the western Atlantic, hawksbill turtles are generally found in clear tropical waters near coral reefs, including the Caribbean, Bahamas, Florida Keys, and southwestern Gulf of Mexico. Hawksbills are the least frequently reported turtle in the Gulf of Mexico (Hildebrand, 1982) and are not expected to be common off the Alabama coast.

Nesting areas for hawksbills in the Atlantic are found in the U.S. Virgin Islands, Puerto Rico, and south Florida. Within the continental U.S., nesting beaches are restricted to the southeast coast of Florida (i.e., Volusia through Dade Counties) and the Florida Keys (Monroe County), as noted by Meylan (1992) and the NMFS and USFWS (1993). No hawksbill nesting occurs near the project area.

Adult hawksbills typically are associated with coral reefs and similar hard bottom areas, where they forage on sponges. Hatchlings are pelagic, drifting with *Sargassum* rafts. Juveniles shift to a benthic foraging existence in shallow waters, progressively moving to deep waters as they grow and become capable of deeper dives for sponges.

2.3.2.5 Marine Mammals

Up to 28 cetacean species occur in the northern Gulf of Mexico, including 7 species of mysticetes (baleen whales) and 21 species of odontocetes (toothed whales) (Jefferson and Schiro, 1997). However, only two cetacean species commonly occur in Gulf coastal waters: the Atlantic spotted dolphin (*Stenella frontalis*) and the bottlenose dolphin (*Tursiops truncatus*) (Davis et al., 1996, 1998). These two are the most likely marine mammals to be found in and near the project area. Two other marine mammals potentially occurring in the region are a sirenian (the Florida manatee, *Trichechus manatus latirostris*) and an exotic pinniped (the California sea lion, *Zalophus californianus*). Of these four marine mammals, only the Florida manatee is a listed species (endangered) under the Endangered Species Act of 1973. All marine mammals are protected under the Marine Mammal Protection Act of 1972.

Atlantic Spotted Dolphin

Atlantic spotted dolphins are widely distributed in warm temperate and tropical waters of the Atlantic Ocean, including the Gulf of Mexico (Perrin et al., 1987, 1994). In the northern Gulf, these animals occur mainly on the continental shelf (Jefferson and Schiro, 1997). During recent aerial and shipboard surveys in the northern Gulf of Mexico for the MMS-sponsored GulfCet II program, Atlantic spotted dolphins were seen at water depths ranging from 22 to 222 m (Mullin and Hoggard, 1998).

Atlantic spotted dolphins can be expected to occur near the project area during all seasons. However, they may be more common during spring. According to Blaylock et al. (1995), it has been suggested that there may be a seasonal movement of this species onto the continental shelf in spring, but data supporting this hypothesis are limited (Fritts et al., 1983). Jefferson and Schiro (1997) indicate that there is a peak in sightings and sightings per unit effort during spring. The GulfCet II data confirm that Atlantic spotted dolphins are present on the shelf during all seasons with the highest number of sightings during spring (Mullin and Hoggard, 1998).

Favored prey of Atlantic spotted dolphins include herrings, anchovies, and carangid fishes (Schmidly, 1981). Mating has been observed in July, with calves born offshore. Atlantic spotted dolphins often occur in groups of up to 50 individuals.

Bottlenose Dolphin

Bottlenose dolphins in the western Atlantic range from Nova Scotia to Venezuela, as well as the waters of the Gulf of Mexico (Hansen and Blaylock, 1994). This species is distributed worldwide in temperate and tropical inshore waters.

Bottlenose dolphins along the U.S. coastline are believed to be organized into local populations, each occupying a small region of coast with some migration to and from inshore and offshore waters (Schmidly, 1981). The NMFS recognizes a northern Gulf of Mexico coastal stock of bottlenose dolphins (Blaylock et al., 1995). It has been defined for management purposes as those bottlenose dolphins occupying the nearshore coastal waters in the Gulf of Mexico from the Mississippi River mouth to about 84ºW longitude and extending from shore, barrier islands, or presumed bay boundaries to 9.3 km seaward of the 18.3-m isobath. Bottlenose dolphins in the project area are presumed to belong to this stock.

During GulfCet II aerial and shipboard surveys, bottlenose dolphins were sighted on the continental shelf off Mobile Bay during all seasons (Mullin and Hoggard, 1998). Water depths of sightings ranged from 30 to 702 m. Bottlenose dolphins were the most abundant cetacean sighted on the continental shelf.

Bottlenose dolphins feed on a variety of fishes, mollusks, and arthropods. Mating and calving occur from February to May. Gestation lasts about 12 months, and the calving interval is 2 to 3 years (Schmidly, 1981). They are found in groups of up to several hundred individuals with group sizes decreasing with distance from shore.

Florida Manatee (Endangered Species)

The West Indian manatee is one of the most endangered marine mammals in U.S. coastal waters. In the southeastern U.S., manatees are limited primarily to Florida and Georgia. This group constitutes a separate subspecies called the Florida manatee that appears to be divided into at least two virtually separate populations -- one centered along the Atlantic coast and the other on the Gulf coast of Florida (USFWS, 1996). Despite concerted research, it has not been possible to develop a reliable estimate of manatee abundance in Florida. The highest single-day count of manatees from an aerial survey is 1,856 animals in January 1992 (Ackerman, 1995).

During winter months, the manatee population confines itself to the coastal waters of the southern half of peninsular Florida and to springs and warm water outfalls as far north as southeast Georgia (USFWS, 1996). As water temperatures rise in spring, manatees disperse from winter aggregation areas. During summer months, they may migrate as far north as coastal Virginia on the east coast and the Louisiana coast in the Gulf of Mexico (USFWS, 1996). On the Florida west coast, sightings drop off sharply north of the Suwannee River (Marine Mammal Commission, 1986), although about 12 to 15 manatees are seen each summer in the Wakulla River at the base of the Florida panhandle. Louisiana is considered the western limit of the Florida manatee's range (Powell and Rathbun, 1984; Lefebvre et al., 1989).

Manatees inhabit both salt and fresh water of sufficient depth (1.5 m to usually less than 6 m) throughout their range. They may be encountered in canals, rivers, estuarine habitats, saltwater bays, and on occasion have been observed as much as 6 km off the Florida Gulf coast (USFWS, 1996)

Based on their known distribution patterns, a few Florida manatees occasionally could be present in Alabama waters during summer months. However, because these animals tend to stay in shallow water, they are considered unlikely to be present in the project area. The Alabama Game and Fish Division (1997) lists them as a Federally endangered species, but with the notation “not believed to occur in Alabama.”

Critical habitat for this endangered species has been designated by the USFWS. All of the critical habitat areas are in peninsular Florida, predominantly along the southwest and southeast coasts (USFWS, 1996).

California Sea Lion

One exotic pinniped species, the California sea lion, is present in the northern Gulf. This species normally occurs only on the Pacific coast. However, a few feral animals are present in the northern Gulf, probably individuals that escaped or were released from marine parks (Schmidly, 1981; Minerals Management Service, 1997).

In the northern Gulf, California sea lions often are seen on or near sea buoys, where they may remain for several months (Schmidly, 1981). There have been sightings off Mobile Bay and near the mouth of the Mississippi River. According to Schmidly (1981), Lowery (1974) reported that a California sea lion visited an oil company barge 51.5 km south of Cameron, Louisiana daily for about a month in August and September 1971, sunning itself on the deck. It seems possible, though unlikely, that a California sea lion could occur in the project area during any season.

California sea lions feed on squids and small fishes. They are polygamous and have a single pup after a gestation period of 11 to 12 months (Schmidly, 1981).

Other Listed Species

In addition to the Florida manatee, endangered marine mammals potentially occurring in the northern Gulf of Mexico include six species of mysticetes (blue whale, *Balaenoptera musculus*; fin whale, *B. physalus;* humpback whale, *Megaptera novaeangliae;* northern right whale, *Eubalaena glacialis*; and sei whale, *B. borealis*) and one odontocete (the sperm whale, *Physeter macrocephalus*). However, the Gulf of Mexico is outside the normal range of most mysticetes, and Bryde’s whale (*B. edeni*, a non-listed species) is the only mysticete commonly occurring there (Davis and Fargion, 1996; Jefferson and Schiro, 1997; Mullin and Hoggard, 1998). The endangered mysticetes are likely to be represented in the Gulf only by occasional strays (Jefferson and Schiro, 1997) and because these large whales prefer deep waters well offshore of the continental shelf (Davis et al., 1998), they would be very unlikely to occur in the project area. Sperm whales are common in the northern Gulf and particularly favor an area just south of the Mississippi River mouth (Hansen et al., 1996; Mullin and Hoggard, 1998). However, these large whales also prefer deepwater habitats and would be very unlikely to occur in the project area. No critical habitat for these endangered large whales is located near the project area.

Another endangered species formerly known from the Gulf of Mexico (the Caribbean monk seal, *Monachus tropicalis*) is now extinct (Schmidly, 1981). The Caribbean monk seal was listed as endangered throughout its range on 10 April 1979. The last reliable sighting of a Caribbean monk seal occurred in 1952. No confirmed sightings have been reported since then. Many scientists believe that the species has been extinct since the early 1950's. No recovery effort is currently being made for this species (NMFS, 1998).

Boyd and Stanfield (1998) reported circumstantial evidence for the presence of monk seals in the West Indies, suggesting that they may not be extinct. The conclusion was based on interviews with fishermen, some of whom chose monk seals when asked to select pictures of marine species known to them. Some fishermen also gave information about size and color that was consistent with many of these seals being monk seals. However, Early (1998) suggested that extralimital arctic seals may account for at least some of the sightings. Even if monk seals are found to be not extinct, they can be assumed not to occur in the project area based on the absence of sightings in the Gulf of Mexico in recent decades.